A TEXT-BOOK OF ZOOLOGY

FOR
PRE-MEDICAL STUDENTS
OF
PANJAB, HARYANA
HIMACHAL PRADESH
AND
JAMMU & KASHMIR
UNIVERSITIES

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PREFACE TO THE NINTH EDITION

The present edition of this book is in full conformity with the latest syllabi laid down for the Pre-Medical class by the universities of Panjab, Haryana, Himachal Pradesh, Jammu and Kashmir. It has been brought out after a careful and extensive revision of the entire text. In this edition, certain topics including, among others, cell structure and DNA, have been rewritten and a few, like theories of evolution and heredity, have been elaborated in order to make them more comprehensive and bring them up-to-date. Important additions and alterations have been made here and there in the text. Subheadings have been introduced in lengthy topics so that the points discussed are easily picked up by average students. Several tables giving comparative account of important topics and animals have heen incorporated for the convenience of the students. Some figures have been redrawn and a few new ones added to supplement the text in a better way. Style of the general survey has been slightly modified. The external characters of at least one representative from each of the phyla and chordate classes, whose types are not included in the syllabus, have been described in detail for better understanding of these groups. Glossary of technical terms and Index, so essential for a science text-book, have been appended at the end. With all this, the book now has 520 pages and 28 tables. Language has been simplified wherever found necessary. Effort has also been made to reduce the printing errors to the minimum.

All these alterations and additions, will, it is hoped, enhance the usefulness of the book.

The authors are grateful to their colleagues for the suggestions given for the improvement of the book and request for more which will be duly acknowledged.

20 July, 1972

Authors

PREFACE TO THE FIRST EDITION

This text-book of Zoology has been designed to meet the needs of the Pre-Medical and B.Sc. Part I students of the Indian Universities. The book contains thirty seven chapters dealing with the various aspects of zoology. The first two chapters are devoted to the fundamental facts of the subject, namely, meaning and scope of zoology, characteristics of life, organization of the animal body, etc. The study of these chapters will prove helpful in understanding the subsequent topics. The third chapter contains the account of Histology of frog. This is followed by the description of some important animal types These types cover the next eighteen chapters, one each for *Amoeba,* Malarial parasite, *Paramecium, Obelia,* Earthworm and Cockroach and twelve for the Rabbit, one for each of the main systems of the body. Then a chapter is devoted to the Principles of Classification and Nomenclature. The succeeding ten chapters contain the General Survey of the Animal kingdom, one chapter for each phylum. This is followed by the synoptic classification of the Animal kingdom in an independent chapter. The last four chapters are confined to the General Zoology—Variations, Heredity and Evolution.

Attempt has been made to incorporate the latest views on the subject with special reference to the reproduction of *Amoeba, Paramecium* and *Plasmodium.* The recent investigation regarding the digestion of food in cockroach has also been included. The anatomy of Rabbit has been described in detail. Special emphasis has been laid on the physiology of the various organs of this animal. The course of the blood through the body with the materials it collects from or distributes to the major organs has been represented by a figure in a simplified manner. A brief description of the heart and eye of sheep has been included for the convenience of the students. In the General Survey of the Animal kingdom, besides the characteristic features of the main groups, brief ecological notes covering the habitat, habits and important features of zoological interest have been given in respect of their common representatives. This would facilitate the students to study the specimens with the aid of this book. Economic importance of main groups of animals is also given to reveal the relation of animals to man. The survey of the animal kingdom has been concluded with its synoptic classification in which effort has been made to give the correct pronunciation of each technical name.

A special care has been taken to use simple language for the convenience of the students. The book has been profusely illustrated to supplement the reading comprehension. The diagrams are simple and clear. The more convenient system of direct labelling has been followed in the figures for saving the time of the readers. Technical terms have been explained where they occur for the first time in the text. At the close of each chapter, test questions are given to enable the students to test their grasp of the subject.

The diagrams given in this book have been made by Sh. Roshan Lal, the artist.

We are grateful to Mrs. J.K. Dhami, Head of the Dept. of Zoology, Government College for Women, Ludhiana, for her many valuable suggestions in the formation of this book.

The authors would thankfully receive the suggestions from the fellow teachers for the improvement of this book.

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CHAPTER 1

Meaning, Scope and Importance of Zoology

To-day we are living in an age of science. There is hardly any sphere of our life, which has not been benefitted by science. Science has provided fast means of communication, increased food output, produced a variety of fibres for clothing, given wonderful medicines, added to household comforts, revolutionized the teaching aids, strengthened military potential and enhanced human personality. But, what, exactly, is sciene ? The term science is derived from the Latin word **scientia,** meaning knowledge. It is used for knowledge gained by actual observation, found correct on verification and put in a systematic manner. In other words, science includes information based on facts. Beliefs, vague impressions and superstitions have no place in science. There are several sciences, each dealing with a specific object. These can be grouped into two main categories : **social sciences** pertaining to social relations of man and **natural sciences** concerned with phenomena of nature. Some natural sciences deal with non-living objects and others with living objects. The former are termed the **physical sciences** and the latter **biological sciences**. The physical sciences include **physics**, **chemistry**, **geology**, and **meteorology**. The biological sciences comprise **zoology** and **botany**.

Science

- Social Sciences
- Natural Sciences
  - Physical Sciences
    1. Physics
    2. Chemistry
    3. Geology
    4. Meteorology
  - Biological Sciences
    1. Zoology
    2. Botany

I. Meaning of Biology, Zoology and Botany

Biology deals with the study of living objects (Greek *bios* =life ; *logos* =study). The living objects are of two types : **animals** and **plants**. Biology, therefore, has two subdivisions. These are called **zoology** and **botany.** Zoology is the study of animals (Gr. *zoon*=animal ; *logos* = study). Botany is the study of plants (Gr. *botane*=plant).

II. Scope of Zoology

Zoology has a wide scope. It deals with all the aspects of animal life. It describes their habits, structure, bodily functions, development, distribution, origin, clssification, relation with one another and with environment, past history and economic importance. The study of each aspect forms a separate branch of zoology. The main branches of zoology are given in the table below—

TABLE 1

Important Branches of Zoology

No.	Branch	Subject
1.	**Morphology**	The study of form and structure.
(*i*)	**External Morphology**	The study of external characters.
(*ii*)	**Internal Morphology**	The study of internal structure.
(*a*)	**Anatomy**	The naked eye study of dissected animals.
(*b*)	**Histology**	The microscopic study of tissues.
(*c*)	**Cytology**	The study of cells.
2.	Physiology	The study of functions of various parts.
3.	Embryology	The study of development from egg to adult.
4.	Ecology	The study of relations between animals and their environments.
5.	Zoogeography	The study of disiribution of animals on earth.
6.	Palaeontology	The study of past life from fossil s.
7.	Taxonomy	The study of classification.
8.	Genetics	The study of variations and heredity.
9.	Evolution	The study of formation of complex animals from simpler ones.
10.	Natural History	The study of habits of animals.
11.	Space Zoology	The study of survival problems of animals in the outer space.
12.	Economic Zoology	The study of benefits of animals to man.
13.	Parasitology	The study of parasites

III. Importance of Zooolgy

The study of zoology has three-fold importance : economic, aesthetic and literary.

1. Economic Value. Study of zoology has a good deal of economic value for mankind.

(*i*) It forms an essential background for the study of medicine, dentistry[1], nursing, veterinary[2] science, agriculture, fishery, poultry[3], dairying, dietetics[4], sericulture[5], bee-keeping, insecticides[6], conservation of wild life, etc. All these sciences are, in fact, the applied branches of zoology. They cannot be studied without a knowledge of the morphology, physiology, ecology and natural history of animals. Zoology, thus, indirectly helps in promoting human health, food and clothing.

(*ii*) Some branches of zoology directly help man, *e*.g. **genetics** aids in improving the race of domestic animals and man himself, **taxonomy** enables us to identify the pests and **parasitology** suggests the control of parasites.

(*iii*) Many animals are beneficial to man. They serve as means of transport and beasts of burden, help in agricultural operations, destroy harmful animals and plants, pollinate flowers, act as scavengers[7], and so on. A knowledge of the structure, habits and requirements of these animal friends acquired from zoology enables us to maintain and use them in a better and scientific way.

(*iv*) Certain animals provide useful articles like leather, fur, wool, ivory, pearls, oil, shellac, honey and medicines. The study of the animals, which furnish the useful materials, goes a long way in imporving the quality and quantity of the products.

(*v*) A few animals are employed in scientific research and the results obtained are applied to man. Our knowledge of heredity, vitamins and enzymes has gathered through experiments on fruit flies, rats and dogs respectively. Drugs are first tested on animals before being used for treating man. Animals preceded man in the outer space.

(*vi*) A few animals are harmful also. The **predators** devour useful animals, parasites cause diseases in them and poisonous ones sting them to death. The **herbivores** destroy crops, fruits and trees. Still others damage human possessions. A study of animal foes (where they live, how they attack and how to keep them away) can save ourselves, our animal friends and our belongings.

(*vii*) Above all, zoology provides a variety of jobs. Teaching and research jobs, professions connected with the applied branches of zoology, employment in the industries dealing with animal products and occupations like animal breeding and selling are all gifts of zoology.

2. Aesthetic Value. Zoology is a subject of considerable interest. The variety exhibited by animal life in form, colour, pattern, behaviour and call notes, is a source of unending amusement for many a person. Keeping pets, maintaining aquaria, bird watching and shell collection

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1. Concerning teeth
2. Domestic animals
3. Domestic fowls
4. Food
5. Silk production
6. Chemicals that kill insects
7. Cleaning agents

are pleasurable hobbies, which can be better pursued with an elementary knowledge of zoology. The art of stuffing birds and deer heads for decoration and colour pattern on cloth and paper have a bearing on zoology. The fundamental knowledge of zoology enables man to acquire or expand aesthetic appreciation of nature and enjoy life.

3. **Literary Value**. Natural history, which is a branch of zoology has enriched literature. Beautiful and interesting animals, particularly birds and butterflies, have inspired many poets to write poems. Animals figure in several stories and dramas. They are quoted in scriptures for the human beings to derive lessons from their life. The behaviour of certain animals has given proverbs like ' snail's speed', crocodile tears', 'sluggish fellow' 'fish out of water' and so on.

Besides this, zoology has revealed unity of all living things. It has enabled man to determine his own place in nature and to adjust himself better to his environment. It has dispelled many superstitions and fears by explaining the mysteries responsible for them. It has disclosed the origin of life and its ever-changing nature through the concept of organic evolution.

Above all, a student of zoology learns the scientific method, which helps him in his job throughout his life.

TEST QUESTIONS

1. What is science ? Define biology, botany and zoology. Enumerate the various branches of zoology and mention the subject they deal with.

2. Discuss the importance of zoology.

3. Explain the following terms :—

Scavenger, Predator, Herbivore, Sericulture, Anatomy, Taxonomy, Aquarium, Parasite, Morphology, Natural Sciences.

CHAPTER 2

Living and Non-Living Things

The various things found in the universe may be divided into three categories : **living, non-living** and **dead**. A living thing is one which possesses life like a horse or a mango plant. A non-living thing, on the other hand, lacks life as a rod of iorn or a piece of stone. A dead thing is that which once possessed life but has since lost it. For instance, a wooden table is a dead thing as it is composed of wood taken from a tree, which at one time was a living organism. A leather shoe is like-wise a dead thing. It is made of skin removed from the body of an animal, which once was a living creature. It is to be noted that a dead thing is simply a changed form of the living thing. There are, thus, actually only two kinds of things : living and non-living.

What is life ?

It has been mentioned in the above para that the living things have life. But, what is life ? This is the question almost as old as man himself. Both philosophers and scientists have been trying to find out an answer to it since long. Two views have emerged from this long thinking. These are **vitalistic view** and **mechanistic view**. The vitalistic view is very old. According to this view, life is due to some mysterious and imperceptible force working in the material of which the living organisms are composed. This view is unscientific and has been replaced by the mechanistic view. According to the mechanistic view, life is due to the result of various physical and chemical changes constantly occurring in the living material. The problem is not fully settled and it is not possible to give a satisfactory definition of life. However, the ways in which life manifests itself, *i.e.* the activities of living organisms, are known and zoology is mainly concerned with the study of manifestations of life, in other words, activities of animals.

Characteristics of Life

The living objects possess certain characteristics or properties, which are not found in the lifeless matter. These are briefly discussed below—

1. **Definite Shape and Size.** The living objects have a constant shape and a fixed average size. All cats, for instance, have a definite size and an unmistakable form. Similarly, all wheat plants can be readily recognized from their size and shape. The non-living objects vary considerably both in form and dimensions. Water may vary from a dew drop to an ocean and it may have any form. A piece of stone likewise varies both in from and size.

2. **Movement.** The living objects have the power to move their parts and many can bodily move from place to place. The non-living objects are, as a rule, motionless. They remain where they are placed.

A few lifeless objects also show movements, *e.g.* water flows in a river and railway engine runs on the track. But the movements of non-living objects are different from those of the living organisms. The force responsible for the movements in a living object arises within its body. Movement in a non-living body is, on the other hand, induced by some outside force. Water flows in a river from a higher to a lower level by the force of gravity. Engine runs on the track with the energy of the fuel, which is not a part of the engine. The movements of living objects are, thus, autonomic or spontaneous, whereas those of the non-living ones are paratonic or induced.

3. **Growth.** The living objects grow in size. Their growth shows three features : (*i*) It is permanent increase in dimensions. (*ii*) It occurs at the cost of substances different from their own body materials . (*iii*) It involves the addition of new parts between or within the older ones. This type of growth is called intussusception. The non-living objects do not show growth in the real sense.

Certain lifeless things may increase in size under special circumstances, *e g*. iorn rod becomes longer on heating. This is, however, not growth as the increase in length is not permanent. The rod returns to original size on cooling. Crystals of copper sulphate become larger when put into a saturated solution of copper sulphate. This again is not a true growth. The crystals have increased in size at the cost of material similar to themselves and moreover they have added more copper sulphate to themselves externally. Such an increase is called accretion.

4. **Metabolism**. Two types of chemical processes constantly take place in the living bodies. These are called **anabolism** and **katabolism.** Anabolism involves the formation of new body-material from the food. It also results in storage of food or energy. It is, thus, a building-up process. Digestion and assimilation of food are important anabolic processes. Katabolism is a break-down process. It leads to the consumption of food and break-down of tissues. Respiration and excretion are instances of katabolism. Anabolism and katabolism together constitute **metabolism**. The organism grows if anabolism occurs at a higher rate than katabolism, while it becomes weak and finally dies if katabolism occurs at a higher rate than anabolism. Metabolic processes are lacking in the lifeless matter.

5. **Irritability**. The animate objects react to changes in their environments. Their reaction is called a **response** and the change in the environment, which causes the reaction, is known as a **stimulus** (plural stimuli). The power of showing response to external stimuli is termed **irritability**. This power enables the living organisms to adapt or adjust themselves to the changed circumstances. Withdrawing one's hand, when pricked with a needle and closing of the leaves of the sensitive plant, when touched are examples of irritability. Non-living objects are ordinarily not irritable. A piece of rock or paper neither moves nor cries, when cut into parts.

Some non-living things, however, respond to change in their surroundings. Metals contract with decrease in temperature, water boils when heated, butter melts on heating, chemicals break up into their constituents when given necessary energy and so on. The responses of living objects differ in their mechanism from those of non-living ones. The non-living things react by changes in their own physical or chemical nature. In contrast, the living objects respond without changing their form, either physical or chemical. Their responses are mostly through movement or secretion.

6. **Reproduction**. Every living object produces another individual of its kind in order to multiply its number. A cat produces kittens and tree seedlings. This activity of life is called **reproduction**. There is no reproduction in inanimate objects. A watch never gives rise to another watch.

7. **Regeneration and Healing**. Living objects often replace parts of their body. For instance, plants periodically shed leaves and regrow them ; animals constantly lose cells covering the surface and lining the alimentary canal and replace them. The living objects can also repair their injuries. The non-living things cannot do so. A bicycle damaged in an accident is never repaired automatically, while injuries of the cyclist are naturally healed up in due course of time.

8. **Definite Individuality**. The living objects exist as complete units. They cannot be kept as parts. We can have half a brick or three-fourth of a piece of chalk, but cannot keep half a cow or three-fourth of a frog.

9 **Organised Life-cycle**. The living objects have a definite life-cycle consisting of different stages, which follow in a regular order. There is birth, growth, maturity, senility or old age and death. There is no orderly cycle of changes in non-living things.

10. **Adaptability**. The living objects have the power to develop variations (changes) in their bodies. This enables them to gradually become better equipped for the struggle for existence. The lifeless things do not change.

11. **Co-ordination of Parts**. The parts of a living body work in a perfect harmony for the benefit of the organism. Non-living objects do not have a unified behaviour.

12. **Cellular Structure**. The living objects are composed of microscopic units, the **cells**, which are in turn formed of a living material, the **protoplasm**. The protoplasm and the cells are not met with in the non-living objects.

TEST QUESTIONS

1. Enumerate the characteristics of life and discuss them briefly.
2. What are 'vitalistic' and 'mechanistics' conceptions of life ? How can you distinguish the living from the non-living things ?
3. What is the difference between a dead thing and a non-living thing ?
4. Explain the terms :—

Anabolism, Stimulus, Protoplasm, Intussusception, Reproduction.

CHAPTER **3**

Animals and Plants

I. Differences

It is quite easy to distinguish between the higher forms of animals and plants. Everyone knows the difference between a cow and a tree. The tree is fixed and does not note our presence. The cow, on the other hand, moves about and notes our approach. Distinction between the lower forms of animals and plants is, however, very difficult as they merge into one another. Moreover, there are certain organisms, which are regarded as animals by zoologists and as plants by botanists. These "plant animals" are green flagellates like *Euglena* (Fig. 27.1). In fact, no clear-cut difference exists between animals and plants. This is because of their common origin.

The following differences may be cited between the animals and plants :—

1. Form and Size. Both animals and plants have a definite form and size. This is because both are living objects. However, the form and size are more constant in animals than in plants. Exceptions occur in both the cases. *Amoeba* is an animal with a variable form and desmids are plants with a definite shape.

2. Movement. Animals can move their parts and most of them have also the power of going from one place to another in search of food. Certain animals, like sponges and corals, are, however, fixed. Plants can only move their parts. They are mostly rooted in the soil and are incapable of locomotion. This is because, being autotrophic, they are not to go about in search of food. Some plants, like *Chlamydomonas*, swim in water freely.

3. Growth. Growth takes place differently in animals and plants.

(*a*) In animals, growth takes place proportionately in all parts of the body. In plants, however, growth is localized at the tip of the stem and a little behind the tip of the root. This is because the animals do not possess unspecialised cells and grow by the division of specialised cells, whereas the plants have a reserve stock of unspecialised cells, called the **primary meristematic cells**, which alone divide for growth.

(*b*) Animals stop growth after the size fixed for the species is reached, but plants continue growing as long as they live. This is why the larger living objects are among the plants. The largest plant in the world is a cypress called Big Tree of Tule. It is growing in Mexico and its trunk is 15 metres in a diameter.

(*c*) In animals, growth consists merely of enlargement of the organs already present in the young one. On the other hand, plants continue producing new organs, like branches and leaves, throughout their life.

4. **Metabolism.** Metabolic activities occur differently in animals and plants.

(*a*) **Feeding.** (*i*) Animals mostly take ready-made organic food for which they are ultimately dependent on the plants. The plants usually take simple inorganic substances like water, carbon dioxide and mineral salts and prepare organic food from these in their own body. This is achieved with the help of green colouring matter or chlorophyll and sunlight. The process is called **photosynthesis**. The plants are, thus, not dependent on the animals for their food-supply. Feeding on organic materials by animals is known as **holozoic** or **heterotrophic nutrition**. Synthesis of food from inorganic sources by plants is called **holophytic** or **autotrophic nutrition** (*ii*) Animals usually have mouth for taking food, plants have none. (*iii*) Animals can take solid food, whereas plants can take food only in solution.

(*b*) **Defaecation.** Defaecation is the elimination of faeces (indigestible food) from the body. Animal food contains a lot of indigestible matter, which has to be eliminated as faeces. Plants absorb only the essential materials and do not defaecate.

(*c*) **Excretion.** Excretion is the removal of nitrogenous waste material from the body. Animals usually have an excretory system for excretion. Plants lack excretory organs. They occasionally get rid of waste material by shedding leaves and bark in which it is deposited beforehand.

(*d*) **Intake of Gases**. Both animals and plants take oxygen for respiration and liberate carbon dioxide as waste material. Plants also take carbon dioxide for preparing organic food and release oxygen. Animals don't do this.

5. **Irritability.** Animals usually have nervous system and sense organs. They, therefore, respond very quickly to the changes in their surroundings. Plants lack nervous system and sense-organs. Consequently, their response is very slow. Some animals, like sponges, have no nervous system and sense-organs and are no more sensitive than plants. A few plants, like *Chlamydomonas*, have receptor organs in the form of pigment spots and are very sensitive to light.

6. **Asexual Reproduction**. Asexual reproduction is wide-spread in plant world. In animals, it occurs only in the lower groups (some invertebrates).

7. **Regeneration**. Power of replacing lost parts is called **regeneration**. It is universal in plants. In animals, it is limited to the lower forms only. In higher animals, regeneration is reduced to healing of wounds only.

8. **Chlorophyll**. Animals mostly lack chlorophyll, whereas the plants usually have it. Exceptions are, however, found on both the sides.

Euglena and Volvox are green animals and fungi and bacteria are non-green plants.

9. Surface Area. Animal body is usually unbranched and most of its organs are internal. Some, like sponges and coelenterates, are exceptional in having a branched body. Plant body, on the other hand, is mostly branched and all of its organs are external. This increases the surface area of the plant-body to receive more sunlight, which is very essential for it. Certain plants are, however, unbranched, *e.g.* palms.

10 Reserve food. Organisms store food in their bodies to ensure continuous supply of energy during unfavourable conditions. The chief reserve food is **glycogen** in animals and **starch** in plants.

11. Cell Structure. (*i*) Animal cell is enclosed in a thin, delicate, living membrane. This makes the animal body soft and flexible. The plant cell is bounded by a thick, rigid and dead wall formed of **cellulose.** This makes the plant body hard and woody. (*ii*) Plant cell contains a large sap vacuole, which has no counterpart in animal cell. (*iii*) Animal cell usually contains a centrosome, whereas the plant cell usually lacks it. (*iv*) Plant cells usually have many types of crystals in them. In the animal cell, the crystals occur only abnormally. (*v*) Lastly, the animal cells are bathed in a solution containing sodium chloride, which is generally toxic for the plant cells.

12. Organization. Animal body is more highly organized than the plant body, having a greater number of tissues, organs and systems in it.

From the fore-going discussion, it may safely be concluded that fundamental similarity exists between animals and plants. They collectively form the organic world. They possess all the characteristics of living objects. They obey the same rules of heredity and they have undergone evolution on similar lines. They only perfrom their activities in different ways, using different structures for similar purposes. There, thus seems to be no valid reason for treating the animals and plants separately except for that of convenience.

II. Interdependence

Animals and plants depend on each other for many of their requirements. Neither the animals can exist without plants nor the plants can survive without the animals.

A. Dependence of Animals on Plants. Animals depend on plants for food (energy), shelter and oxygen.

1. Food. (Energy). As already stated, the green plants prepare organic food from simple inorganic substances like water, carbon dioxide and mineral salts, by photosynthesis. From this food, they derive energy for their metabolic activities. The animals are unable to do this and, therefore, depend on the green plants for food (energy) . The herbivores (plants eaters) and frugivores (fruit eaters) directly depend on plants. These animals include a large number of insects, some fishes, many birds and several mammals. The carnivores (flesh eaters) also depend on plants for food, but indirectly. They feed on other animals, which in turn eat plants, *e.g.* the lions take deer that flourish on grass.

2. Shelter. Plants provide shelter to a variety of animals. Some protozoons and many nematodes live inside the plant parts. A number of insects occur on the plants, hiding under bark and leaves. Several birds rest and nest on the trees. Smaller mammals like squirrels and monkeys live on the trees, while larger ones rest under them in sun and rain.

3. Oxygen. Green plants absorb carbon dioxide from the atmosphere, retain carbon for use in food synthesis and release oxygen. Thus, they purify the air for the animals to breathe.

B. Dependence of Plants on Animals. Plants depend on animals for carbon dioxide, pollination, dispersal, food and ploughing of soil.

1. Carbon Dioxide. Animals take oxygen and release carbon dioxide during respiration. This carbon dioxide is absorbed by the green plants for food synthesis.

2. Pollination. Pollination is the process of carrying pollen grains (male cells) to the stigma (female part) of the flowers. Many animals, particularly the insects like bees, ants, butterflies, moths and bugs, bring about pollination in plants. Without these pollinators, many plants will fail to produce fruits and seeds and will disappear from the world.

3. Dispersal. Plants, being rooted in the soil, have a problem of sending their progeny to new localities. Many animals help the plants in this work. Frugivorous birds and mammals (squirrels, bats, rats, etc.) gather fruits of plants for eating and scatter their seeds over new places.

4. Food. Animals increase the fertility of the soil by adding to it their dead bodies and excreta (urine and faeces). This promotes plant growth. Insectivorous plants (*e.g. Drosera*, *Dionea*, *Nepenthes*, etc.) capture and digest insects in special traps. Bacteria live in the digestive tract of all sorts of animals and get nourishment as well as shelter.

5. Ploughing of Soil. Burrowing animals like earthworms, ants, rats, moles and rabbits, make the soil porous. The porous soil entraps air for the respiration of roots, allows sun rays to penetrate for killing bacteria and fungal spores and results in rapid absorption of water and easy penetration of roots. All this promotes plant growth.

TEST QUESTIONS

1. Discuss the differences between animals and plants.
2. Explain the following terms.
   Chlorophyll, Photosynthesis, Autotrophic and Heterotrophic Nutrition, Defaecation and Glycogen.
3. Discuss the interdependence of animals and plants.

CHAPTER **4**

Cytology

Cell Principle

It has been stated earlier that the living objects are composed of units called **cells**. The cells are usually extremely small and invisible to the naked eye. Therefore, their existence became known only after a magnifying instrument, the **microscope**, was invented. They were first seen in a thin slice of cork (a plant tissue) by Robert Hooke, an Englishman, in 1665. They were subsequently seen in many animals and plants by other workers. In 1838-39, two famous German biologists, namly, Schleiden, a botanist, and Schwann, a zoologist, separately put forward the **cell theory**. This theory stated that all living objects were built of cells. The cell theory has now been slightly modified. In the modified form, it has been found to be universally true and, hence, given the status of the **cell principle**. The cell principle states that all organisms are composed of cells and their products. The intercellular substance found in many tissues is not cellular, but secretion or product of cells.

The cell is not only the unit of structure in a living object, but also a unit of function. All the activities like digestion, growth, respiration, response to stimuli, reproduction, etc. of even the most complex organism, in final analysis result from its cells. Further, a cell is the minimum biological unit capable of maintaining and propagating itself. Each cell, though integrated with the functioning of the body as a whole, can act independently of others. A cell may grow, secrete, divide or die, while its adjacent cells may be in a different physiological state.

The study of cell is known as **cytology.**

Protoplasm

Protoplasm is the living material of which the cells are formed. It carries on the metabolic activities of the living objects. So long as the protoplasm is able to carry on metabolic activities, the organism is alive ; the moment these activities cease, the organism dies. Life is, therefore, simply the activities of protoplasm. Huxley (1868) has, thus, very appropriately described the protoplasm as the "**physical basis of life.**"

Protoplasm differs from organism to organism and even in different organs of the same organism. Thus, the protoplasm of a frog is

different from that of a rabbit and the protoplasm of the liver differs from that of the kidney. Yet, the protoplasm of all organisms has some common properties. These properties are of three types : physical, chemical and biological or physiological.

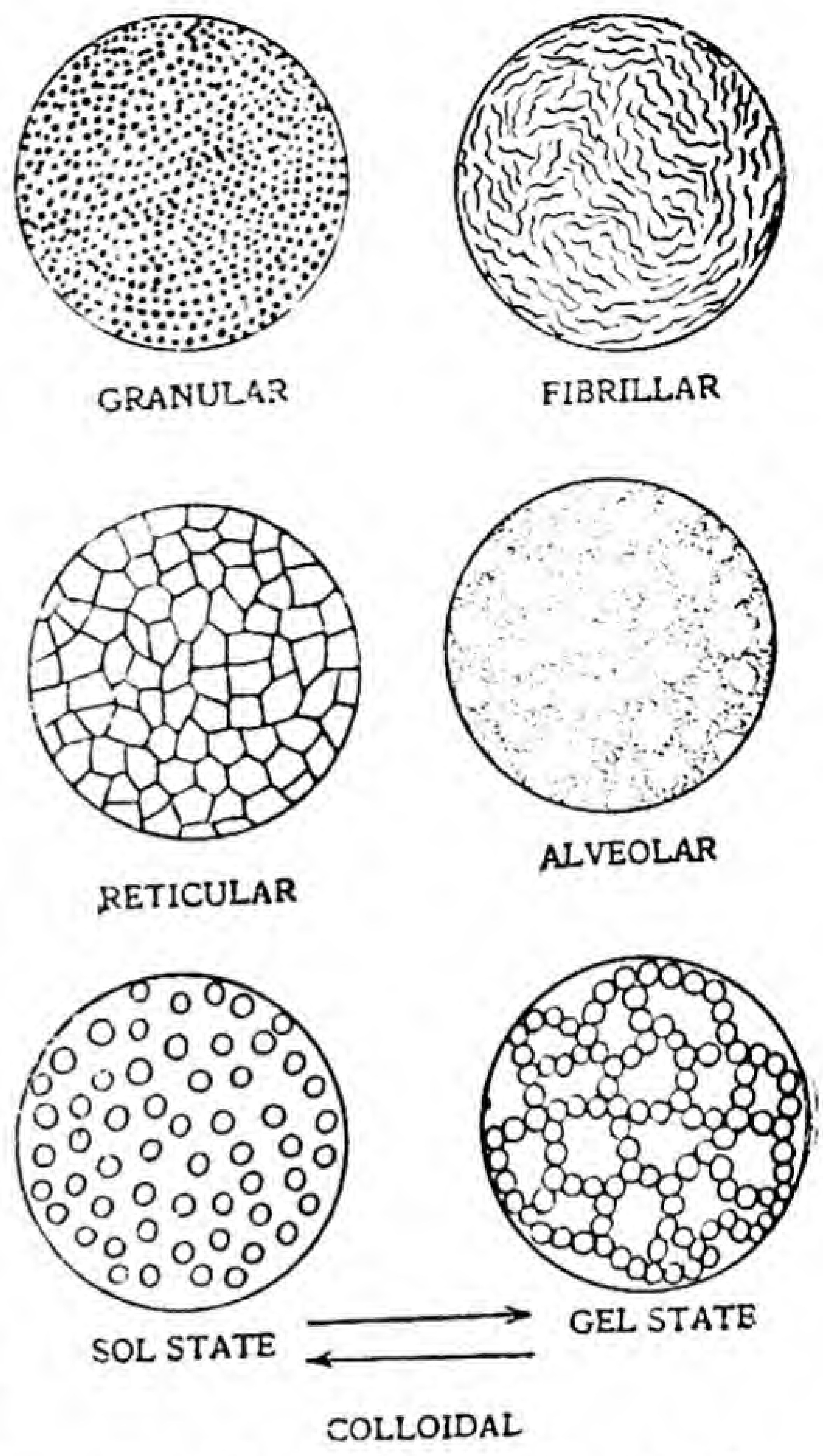


Fig. 4.1. Physical structure of protoplasm

I. Physical Properties of Protoplasm.

1. Appearance. Living protoplasm is a slightly greyish jelly, which is transparent or translucent, somewhat viscous but capable of flowing, and a bit heavier than water.

2. Structure. Early investigators studied dead stained protoplasm and formulated the following theories about its physical nature (Fig. 4.1).

(*i*) Granular theory according to which protoplasm consists of fine granules evenly distributed in liquid medium.

(*ii*) Fibrillar theory which gives protoplasm the appearance of threads suspended in fluid.

(*iii*) Reticular theory in which protoplasm is thought to be composed of network with the meshes filled with a liquid.

(*iv*) Alveolar theory which describes protoplasm as a viscid matter having numerous small fluid-filled spaces or alveoli in it.

The different appearances of protoplasm as described by the above theories are regarded as artefacts produced by fixatives and stains, which coagulate the protoplasm. These theories, therefore, have historical value only.

The modern and generally accepted theory about the physical nature of protoplasm is the **colloidal theory**. According to this theory, the protoplasm is a complex mixture of two types of aqueous solutions : a **colloidal solution** of organic compounds (proteins and fats) and a **molecular solution** of both inorganic and organic compounds (salts and sugars). A substance when mixed with water or any other liquid may form a true solution, a suspension or a colloidal solution. This depends on the size of the particles of the substance mixed with a liquid. Very fine particles, less then 0·000,001 mm. in diameter,

form a clear, transparent mixture called the **true** or **molecular solution**. Substances that form true solution are called **crystalloids.** Sugar and table salt produce such a solution in water. Very large particles, larger than 0·000,1 mm., form a turbid or opaque mixture known as the **suspension**. The particles of a suspension settle out in response to gravity if it is kept undisturbed for some time. Muddy water contains clay particles in suspension. Particles intermediate in size between those of a true solution and a suspension, *i.e.* from 0·000,001 to 0·000,1 mm., form a somewhat cloudy or translucent mixture termed the colloidal solution. A colloidal solution is stable and its particles do not settle out on standing. It often has a sticky glue-like consistency, hence its name (Gr. Kolla=glue ; eidos=form). Substances that form colloidal solution are called **colloids**.

3. **Change in Consistency.** The consistency of protoplasm varies under different conditions from a more fluid **sol** state to a more solid **gel** state and vice versa This change is brought about by a variation in the distribution of colloidal particles. When the particles are evenly distributed in the liquid medium, the mixture can flow easily and is said to be in a sol state. When the particles are arranged in a net-work with the liquid filling the meshes, the mixture becomes semisolid gel and stops flowing.

4. **Formation of Surface Membrane.** The protoplasm forms a thin limiting membrane at the surface. This membrane regulates the passage of materials into and out of the protoplasm.

II. Chemical Properties of Protoplasm. Protoplasm contains about twenty elements, viz. oxygen, carbon, hydrogen, nitrogen, calcium, phosphorus, potassium, sulphur, chlorine, fluorine, sodium, magnesium, iron, copper, cobalt, zinc, silicon, manganese, iodine and nickel. Of these, the first four are the principal elements as they alone constitute about 95% of the protoplasm. The next nine elements form a little less than the remaining 5% of the protoplasm. The last seven are the trace elements. All the elements, except oxygen, occur in the form of chemical compounds, both organic and inorganic. All the contituents of protoplasm by themselves are non-living, but, together, they produce living substance. This is possible only in living objects.

I. Inorganic Compounds. Inorganic compounds of the protoplasm include water, salts, and gases.

1. **Water.** Water forms about 80% of the protoplasm. It serves many important functions. It acts as a solvent in which other compounds are dissolved or suspended. It enables the chemicals (food, waste materials, etc.) to move through the protoplasm. Its property of breaking many compounds into ions helps in bringing about chemical reactions. It keeps the organs moist to give them free movement upon each other. It protects the protoplasm from sudden changes in the temperature of the surroundings as it neither absorbs nor loses heat easily. Its high surface-tension imparts consistency to protoplasm. In fact, it is essential for all life activities.

2. Inorganic Salts. Inorganic salts form only 1—2% of the protoplasm. The main salts are chlorides, carbonates, phosphates and sulphates of calcium, potassium, sodium, magnesium and iron. They regulate the vital functions of the cell. They also maintain osmotic pressure in the cell.

3. Gases. Gases like oxygen, nitrogen, carbon dioxide and ammonia are found dissolved in the protoplasm. The first two diffuse into the protoplasm from the atmosphere and the latter two are by-products of the chemical reactions occurring in the protoplasm. Oxygen serves to release energy by oxidation of foods. Carbon dioxide is produced during oxidation as a waste material and is eliminated. Nitrogen, being inert, takes no part in cell reactions.

II. Organic Compounds. Organic compounds of the protoplasm include carbohydrates, lipids, proteins, nucleic acids, enzymes and regulatory substances.

1. Carbohydrates. Carbohydrates form only about 1—2% of the protoplasm. They are compounds of carbon, hydrogen and oxygen. Hydrogen and oxygen always occur in the ratio of 2 : 1 as in a molecule of water. The carbohydrates include sugars and starches.

(*i*) **Sugars.** The sugars are simple carbohydrates. They mainly act as fuel, liberating energy by oxidation. They are of two types : single or simple sugars, called **monosaccharides**, having 2—6 carbon atoms and double sugars, called **disaccharides**, formed by the combination of two monosaccharide molecules. The important single sugars are pentoses like **ribose** and **deoxyribose** and hexoses like **glucose** and **fructose**. The important double sugars are **sucrose**, **lactose** and **maltose**.

(*ii*) **Starches.** The starches are complex carbohydrates. They are formed by the combination of several monosaccharide molecules. They serve two functions of diverse nature, viz. support and storage. The common starches are **chitin** and **cellulose**, which serve for support and **glycogen** or **animal starch** that forms reserve food. When required, glycogen can change into sugar for use as a source of energy.

2. Lipids. Lipids form about 3—7% of the protoplasm. They are compounds of carbon, hydrogen and oxygen like carbohydrates, but have lower oxygen content. They include fats, waxes, steroids and four fat-soluble vitamins, viz. A, D, E and K. The fats are composed of fatty acids combined with glycerol. They are greasy in nature. They may be solid at ordinary temperature like bacon fat or liquid like cod or shark liver oil. Fats serve both as fuel and as components of protoplasm. They produce much more energy per gram than the carbohydrates and thus form better food-reserves. Fats have other uses also. They form an insulating layer under the skin in polar bears and whales and form protective and shock-absorbing cushions around eye-balls and kidneys. They also form nuclear and cell membranes and control the passage of materials in or out of protoplasm.

Special form of lipids, called phospholipids, occur in mitochondria

and microsomes. They have nitrogen and phosphorus besides glycerol and fatty acids. They help in cell metabolism.

3. **Proteins**. Proteins form about 10—30% of the protoplasm. They are compounds of carbon, hydrogen, nitrogen and sulphur. Some have traces of phosphorus also. The molecules of proteins are extremely large because they are formed of innumerable links, the **amino acids,** joined together. The linkage of two amino acids is known as a **dipeptide,** of three, a **tripeptide**, and of many, a **polypeptide**. When very large, the polypeptides, are called **peptones.** The peptones combine to form the proteins. The proteins are of two types according to the shape of their molecules : fibrous and globular.

(*i*) **Fibrous Proteins**. The fibrous proteins have amino-acid chains spirally wound to form fibres. They are insoluble in water and are contractile. The common examples are : **collagen** of connective tissues, **myosin** of muscles and **keratin** of hair, claws, feathers and horns.

(*ii*) **Globular Proteins**. The globular proteins have amino-acid chains coiled about themselves to form spheres. They are soluble in water and are noncontractile. The common examples are **albumen** or white of eggs, **haemoglobin** or red colouring matter of blood, most **enzymes** and large portions of hormones.

The proteins are specific in occurrence, *i.e.* every species of animals and plants possesses a set of proteins found in no other living thing. Closely related (very similar) organisms share many of their proteins with one another, whereas distantly related (dissimilar) organisms share few.

The proteins primarily serve to build the protoplasm. Besides this, they also help in forming enzymes and hormones and in releasing energy by acting as fuel.

4. **Nucleic Acids**. Nucleic acids form about 2% of the protoplasm. They are compounds of carbon, hydrogen, oxygen, nitrogen and phosporus. They have large complex molecules with high molecular weight (over 1,000,000) and composed of numerous (12,000) smaller molecules. Two nucleic acids are known : **ribonucleic acid** and **deoxyribonucleic acid**. The names of these acids are generally abbreviated to RNA and DNA respectively. They were first observed in the nucleus, hence their name. The ribonucleic acid is now known to occur in the cytoplasm also. It helps in the synthesis of proteins. The deoxyribonucleic acid in combination with proteins forms the chromosomes, which carry the hereditary material of the organism. It is, thus, responsible for heredity. It also controls cell metabolism.

5. **Enzymes**. Enzymes are mostly protein in nature. They exist in the living protoplasm and there is a very large number of them in every cell. They enable the protoplasm to carry on the multitude of its chemical reactions at ordinary temperature. They are specific, are needed in traces and themselves remain unchanged in the reactions they cause in other substances. They are consequently described as the **organic catalysts.** They mostly work within the cells, but a few like

ptyalin, pepsin, amylase, etc. are discharged into the digestive tract, where they produce chemical reactions in the food.

6. Regulatory Substances. These substances include **vitamins** and **hormones**. These substances occur in very small amounts, but play a very significant role in the maintenance of normal metabolism of the living material.

III. Biological or **Physiological Properties of Protoplasm.** Biological properties of protoplasm include the activities that show life in organisms. These properties have been discussed in chapter 2.

Cell Structure

Recently the electron microscope has greatly added to our knowledge of cell structure gained earlier with the help of a compound microscope. Figure 4.2 shows most of the bodies visible in animal cells under a compound microscope, while the figure 4.3 represents the structure of an animal cell based on electron micrographs.

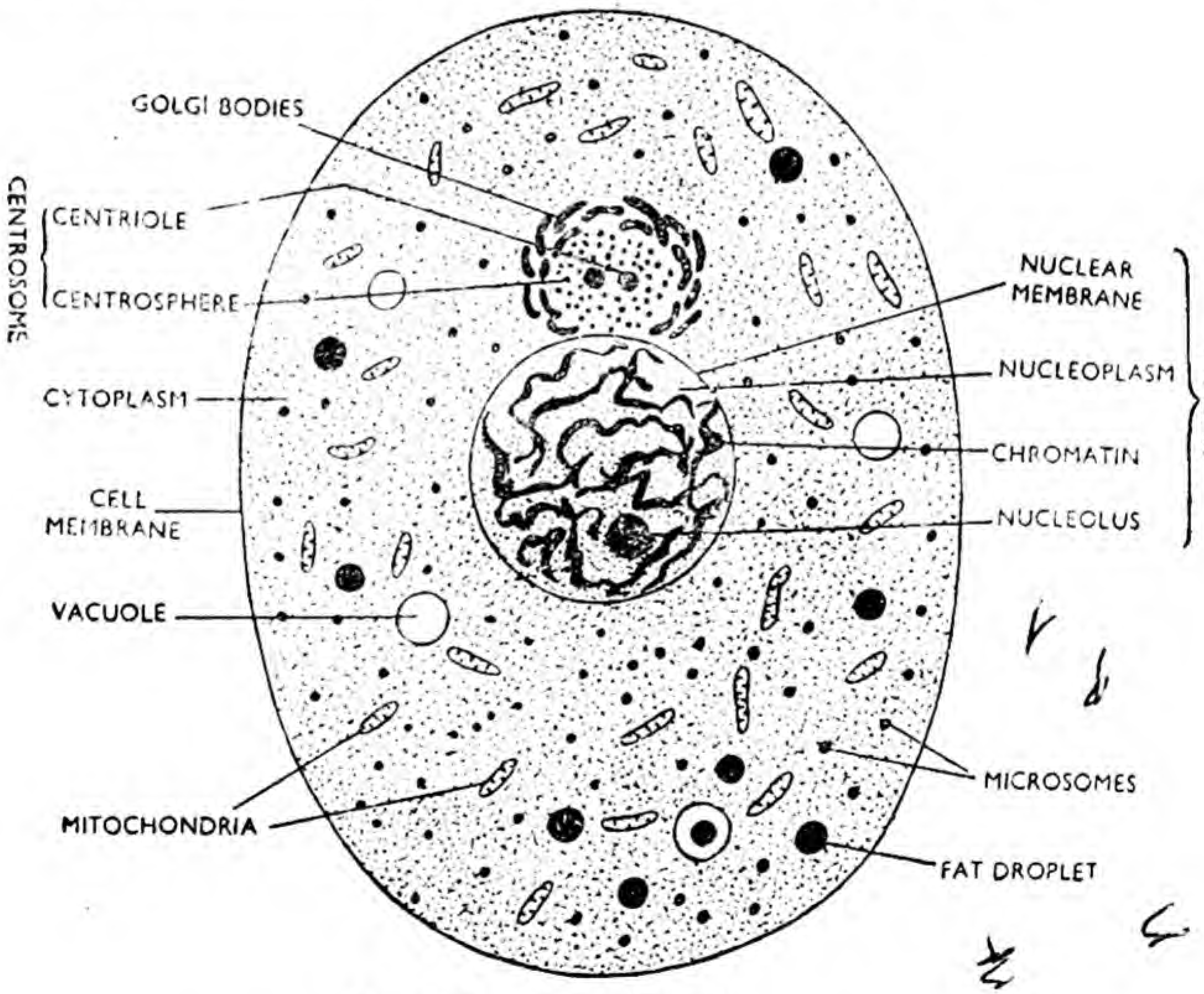


Fig. 4.2. An animal cell

Cells vary greatly in size, shape, function and even internal structure not only in different animals but also in different parts of the same animal. In fact, there are many types of cells like epithelial, muscle, nerve. The following account does not pertain to any particular type of cell, but giv structures common to most cells.

A cell i: ccmposed of the living material called **protoplasm.** The

protoplasm is differentiated into two main regions : the peripheral **cytoplasm** or **cytosome** and the central **nucleoplasm** or **nucleus.**

1. Cytoplasm. The cytoplasm consists of a more or less transparent and somewhat viscous (sticky) semifluid material, the **ground substance or hyaloplasm**, which forms an envelope called the **cell membrane** or **plasma membrane** at the surface and contains granules and several types of structures, the **cell organelles**, suspended in it. In free cells such as, one-celled animals (*Amoeba* and others), the cytoplasm shows an outer, narrow, relatively firm zone, the **ectoplasm**, around a central relatively fluid mass, the **endoplasm**. The cells, which occur in close contact with one another, as in many-celled animals, lack ectoplasm. The cells lining the tubes, *e.g.* alimentary canal, however, have ectoplasm on their exposed sides.

The structures suspended in the hyaloplasm are of two chief types : the **living** or **protoplasmic structures** capable of growth and multiplication and **non-living** or **deutoplasmic structures** incapable of growth and multiplication. The living structures include the **endoplasmic reticulum** or **ergastoplasm**, **centrosome** or **cell centre**, **mitochondria**, **Golgi apparatus** or **Golgi bodies** and **ribosomes** or **microsomes**. The non-living materials comprise foods (starch grains, protein granules, fat droplets), secretions (enzymes, hormones), excretions or wastes (urea), minute sacs called **lysosomes**, vacuoles and fine fibrils (*e.g.* contractile **myofibrils** and conducting neurofibrils) of protein.

(*i*) **Cell Membrane.** The cell membrane forms a very thin and delicate covering around the cell. It is living, being an integral part of the cytoplasm inside it. The cell membrane consists of two layers of lipid molecules with a layer of protein molecules on either side. The cell membrane serves many functions. It maintains the individuality and form of the cell and keeps its contents in position. It permits the entrance of useful materials, like food, hormones and oxygen into the cell and exit of waste materials, such as urea and carbon dioxide, out of the cell. The cell membrane is, thus, selectively permeable.

(*ii*) **Endoplasmic Reticulum.** The endoplasmic reticulum is visible only in electron micrographs. It is an extensive double-walled network traversing most of the cytoplasm. It has a highly variable form and can fragment and reform its parts. The membranes of the reticulum are continuous with the cell, nuclear and Golgi membranes. The endoplasmic reticulum is often associated with ribosomes (described ahead) and appears rough or granular. It may be free of ribosomes when it looks smooth. The endoplasmic reticulum serves many functions. It brings about quick transport of materials from one part of the cell to another. It forms nuclear membrane around the daughter nuclei in cell division. It holds a variety of enzymes that help in the synthesis of important substances.

(*iii*) **Centrosome.** The centrosome usually lies near the nucleus. It consists of two minute rods, the **centrioles**, surrounded by a small mass of lightly-staining and homogeneous cytoplasm, the **centrosphere**. Electron microscope reveals that the centrioles have the form

of cylinders lying at right angles to one another. They resemble the flagella and cilia in structure, each consisting of nine outer fibrils arranged in a ring round two central fibrils. The centrioles determine the plane of cell division. They are, however, not essential for cell division, as plant cells divide without them.

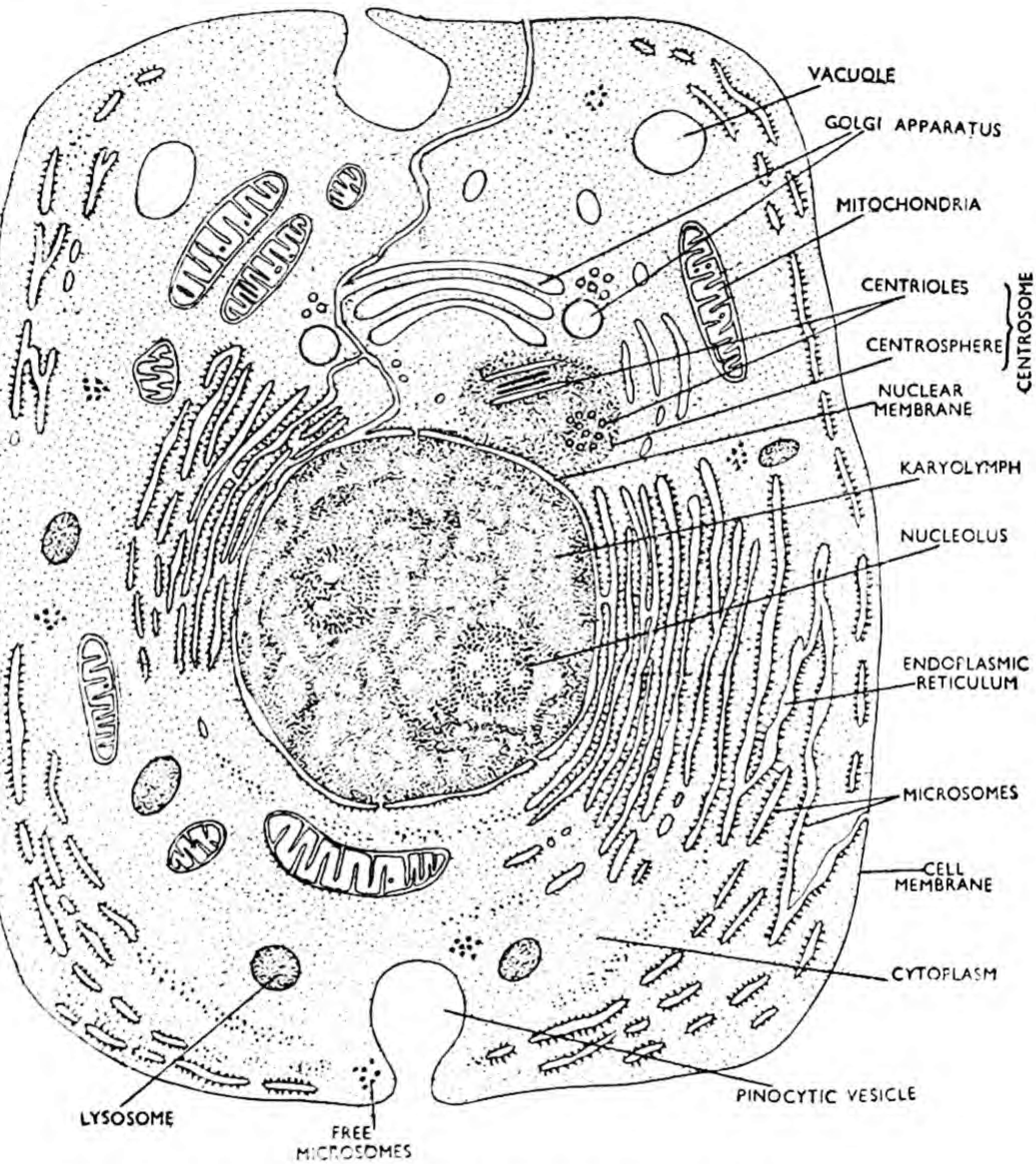


Fig. 4.3. A diagram of an animal cell based on electron micrographs

(*iv*) **Mitochondria**. The mitochondria are small rod-like bodies usually scattered throughout the cytoplasm. The electron microscope reveals that a mitochondrion is a double-walled vesicle filled with a granular **matrix**. The inner wall is thrown into characteristic infoldings, **the cristae** (Fig. 4.4). The mitochondria are composed of proteins and lipids. They carry on their cristae respiratory enzymes, which catalyze oxidation of food to release energy for cell activities. They

are, thus, the powerhouses of the cell. Their number is directly proportional to the activity of the cell. Growing, dividing and secreting cells have more mitochondria than others.

(*v*) **Golgi Apparatus.** The **Golgi apparatus** generally occurs near the centrosome. It appears as a coarse network when seen with the light microscope. Electron micrographs show it as a bundle of flattened sacs, devoid of granules, having swollen ends and associated with large vacuoles and groups of small vesicles. The Golgi apparatus probably plays a role in the storage of cell secretions. It perhaps also serves to modify and temporarily store certain compounds particularly lipids. It may also maintain a proper concentration of water in the cell.

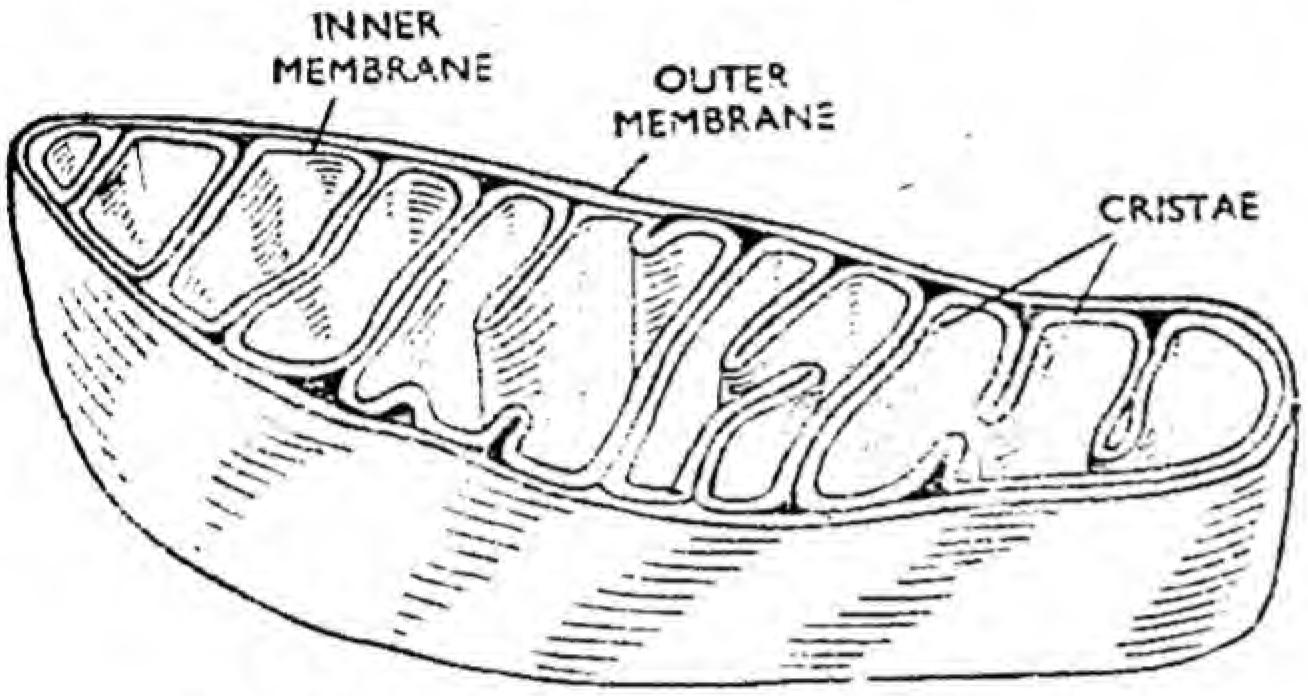


Fig. 4.4. Mitochondrion in section

(*vi*) **Ribosomes.** The ribosomes are very tiny particles visible only in electron micrographs. They are often associated with the endoplasmic reticulum, but may occur free in the cytoplasm also. Protein synthesis occurs on their surface guided by RNA received from the nucleus.

(*vii*) **Lysosomes.** The lysosomes are minute sacs with a single membrane wall. They isolate digestive enzymes from the cytoplasm and store them, thereby keeping the cell from digesting itself.

2. **Nucleus.** The number, shape and position of the nucleus, vary greatly in different cells. Usually, however, there is a single nucleus, it is spherical and lies near the centre of the cell. It is bounded by a thin but distinct **nuclear membrane.** Electron micrographs indicate that the nuclear membrane is two-layered and porous. It is selectively permeable and controls the flow of materials into and out of the nucleus. Within the nuclear membrane is a dense colourless fluid, **karyolymph** or **nuclear sap.** The latter contains a number of irregular deeply staining threads and granules just beneath the nuclear membrane. These threads and granules are together known as the **chromatin** because of their affinity for certain dyes. The chromatin is composed of DNA and proteins. When the cell is not dividing, the threads of the chromatin material are long and slender and lie irregularly so as to give the appearance of a network. During cell-division, they become short, thick and conspicuous and are termed the **chromosomes.** The chromosomes bear the hereditary units, the **genes.** The latter determine the characters of every species of animals and carry characters from one generation to another. The number of chromosomes is fixed for each species of animals. The karyolymph also contains one or more large rounded bodies, the **plasmosomes** or **nucleoli.** These are densely-packed masses of granules without any

limiting membrane. They consist largely of ribonucleic acid (RNA). Their RNA passes out into the cytoplasm, where it becomes associated with the ribosomes and directs protein synthesis.

Both cytoplasm and nucleus are necessary for the normal activities of the cell, but the exact role of each in the metabolism of the whole is not yet clearly known In general, the cytoplasm is the seat of metabolic processes including synthesis of proteins, formation of enzymes which facilitate the various chemical reactions, and oxidation that yields energy. It is also a store-house of the raw materials needed for metabolism in both the cytoplasm and the nucleus. The nucleus is responsible for inheritance. It also guides the protein synthesis in the cytoplasm. It produces nucleic acids, DNA as well as RNA. The DNA is an important constituent of chromosomes. It is often described as the "memory" of the cell because it carries genetic information for transmission to the next generation and instructions for the working of the cell. The DNA acts as a template (mould) for the formation of RNA. The RNA is stored in the nucleoli. From here, it passes out into the cytoplasm and functions as a 'messenger' conveying instructions from the DNA (chromosomes) of the nucleus to the cytoplasm. In the cytoplasm the messenger RNA is received by the microsomes, where it directs the synthesis of specific proteins.

Summary of the cell structure is given below :

- Cell
  - Cytoplasm
    - Cell Membrane
    - Hyaloplasm
      - Protoplasmic Inclusions
        1. Endoplasmic Reticulum
        2. Centrosome—
           - Two centrioles
           - Centrosphere
        3. Mitochondria
           - Wall with cristae
           - Matrix
        4. Golgi Apparatus
        5. Microsomes or Ribosomes
      - Deutoplasmic Inclusions
        1. Food Materials (Starch Grains, Protein Grains, Fat Droplets)
        2. Secretions (Enzymes, Hormones)
        3. Excretions (urea)
        4. Lysosomes
        5. Vacuoles
        6. Fribrils
  - Nucleus
    - Nuclear Membrane
    - Karyolymph
      1. Chromatin Threads
      2. Nucleoli

DNA or Deoxyribonucleic Acid

(*a*) **Molecule** (Fig. 4.5 *A*). The DNA molecule is one of the largest molecules known in chemistry. It is 30,000 Angstroms* long and 20 Angstroms thick. It has very high molecular weight, over one million.

*Angstrom is a measure of molecules. It is written as A°.

One A° $= \frac{1}{10.000,000}$ m m.

It is very complex in structure, being composed of 12,000 smaller molecules. The smaller molecules exist as two nucleotide chains joined together by hydrogen bonds. A nucleotide in turn consists of

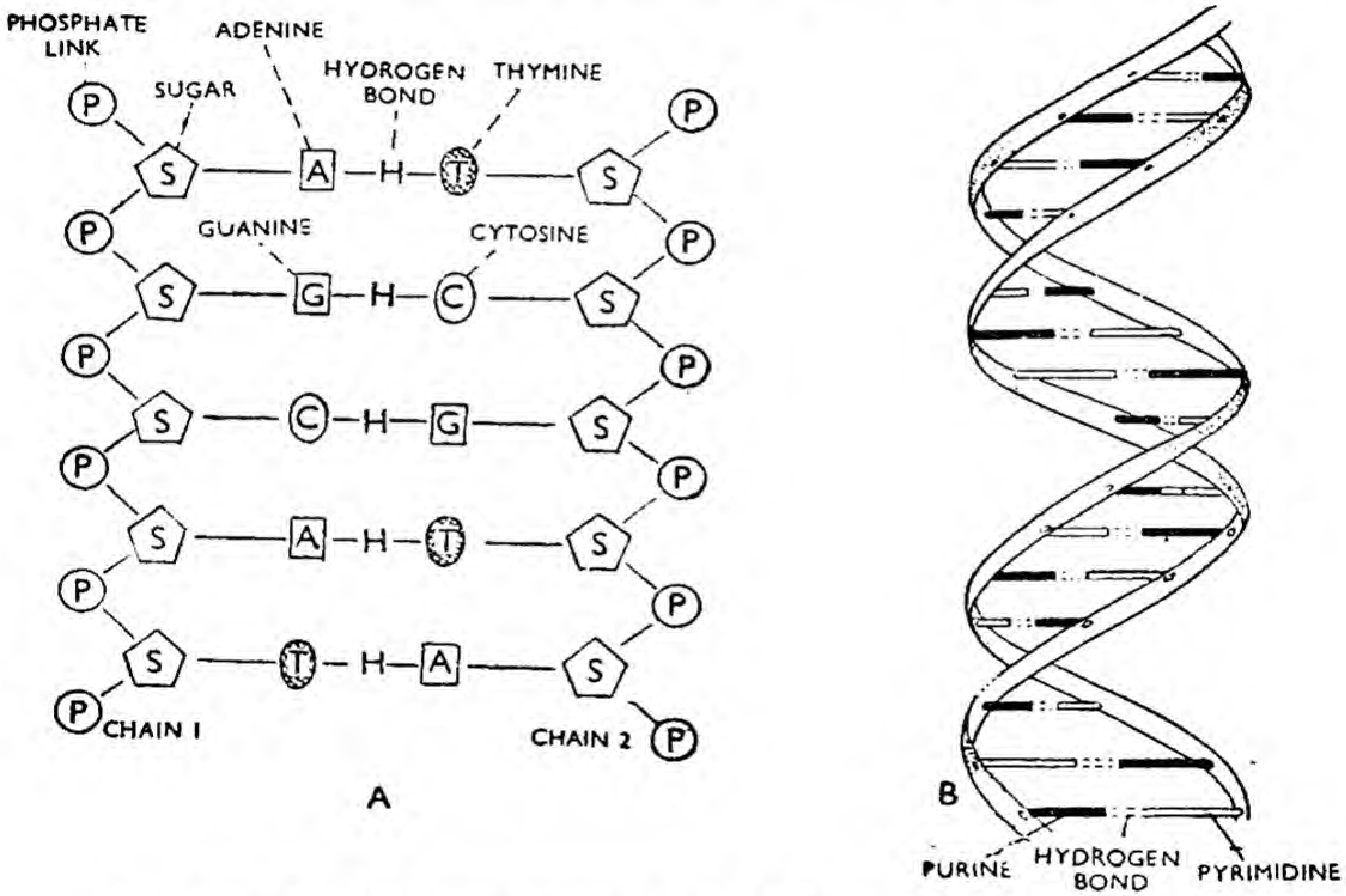


Fig. 4 5. A. Molecular structure of DNA
B. Model of DNA according to Watson-Crick concept

three types of molecules : a molecule of pentose sugar called **deoxyribose** (*S*), a phosphate or phosphoric acid molecule (*P*) and a base molecule. The base involved is either a **pyrimidine** or a **purine**. A pyrimidine consists of four carbon and two nitrogen atoms arranged in a hexagonal ring. There are two pyrimidines, namley, **thymine** (*T*) and **cytosine** (*C*). Purine comprises a pyrimidine ring plus a side ring of one carbon and two nitrogen atoms. Purines are also two, *viz.* **adenine** (*A*) and **guanine** (*G*). The link provided by hydrogen atoms (*H*) is between the bases of the two nucleotide chains. The linkage is not at random. Thymine is always joined to adenine and cytosine to guanine. There are, thus, only four combinations : $A—T$, $T—A$, $C—G$ and $G—C$.

These combinations are arranged in a specific sequence in each animal and this sequence is called its '**code**'. The possible sequences are infinite and they can be repeated as often as possible. This gives an infinite variety to the DNA molecule.

(*b*) **Model** (Fig.4.5. B). Two biochemists, D.S. Watson of America and F.H.C. Crick of Britain, in 1953 designed a model of DNA molecule to explain its structure. This got them the 1962 Nobel Prize. According to this model, the DNA molecule consists of two long parallel bands joined together by short horizontal bars at regular

intervals and spirally coiled about each other to form a double helix. In other words, the molecule has the form of a twisted ladder or spiral staircase. The vertical bars of the ladder are composed of phosphate

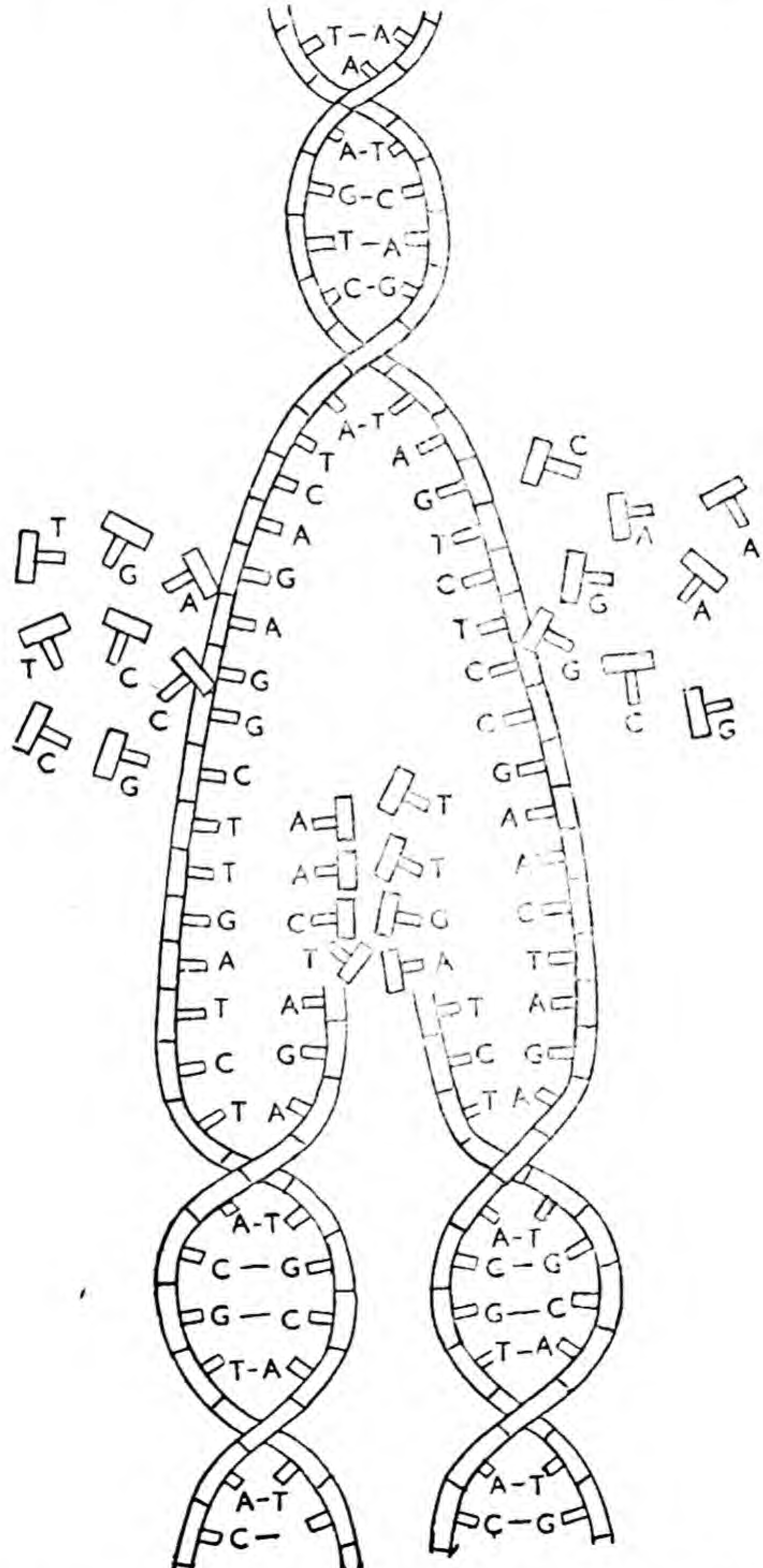


Fig. 4.6. Replication of DNA molecule. The molecule uncoiles and splits into two chains. Free nucleotides of the nucleus join these chains at appropriate places, thus forming two molecules, which retwist.

and deoxyribose sugar while the rungs of the ladder are formed of pyrimidines and purines linked by hydrogen atoms.

(*c*) **Replication** (Fig. 4.6). An important property of DNA molecule is **replication**, *i.e.* power to build another molecule of its own kind. For replication, the DNA molecule unwinds and splits into its two constituent nucleotide chains by break down of hydrogen bonds. The nucleus contains free nucleotides of various types as raw material. Thymine and cystosine bases of the unzipped (split) nucleotide chain are respectively joined by adenine- and guanine-containing free nucleotides. This produces two identical DNA molecules, each of which retwists into a double helix.

(*d*) **Role.** DNA plays a dual role in life : transmission of hereditary characters and synthesis of proteins.

(*i*) **Transmission of Hereditary Characters.** DNA is the chief component of the chromosomes. By replication it doubles the number of chromosomes prior to cell division. With the result, identical reprints of the parent cell go into the daughter cells.

(*ii*) **Synthesis of Proteins.** DNA molecule not only replicates another DNA molecule similar to itself. but also produces RNA molecules. The RNA molecule differs from DNA molecule in having ribose sugar in place of deoxyribose and uracil pyrimidine in place of thymine. From the nucleus, RNA passes out into the cytoplasm and settles over the ribosomes. This is said to be the messenger RNA as it carries instructions from the DNA to the ribosomes to guide the synthesis of specific proteins. For every protein there is a definite type of messenger RNA and this is produced by a particular part (gene) of DNA molecule (chromosomes).

Cell Multiplication or Division

Growth in a many-celled animal fundamentally consists of an increase in the number of its cells. The new cells arise by the division of the pre-existing cells. The cells divide in three ways : **amitosis, mitosis** and **meiosis**.

I. Amitosis. Amitosis is a very simple process. It is, therefore, also called the **direct division.** In this method, the nucleus elongates and develops a constriction around its middle (Fig. 4.7). The constriction gradually deepens and finally cuts the nucleus into two daughter nuclei, which may be of unequal size. A similar constriction appears

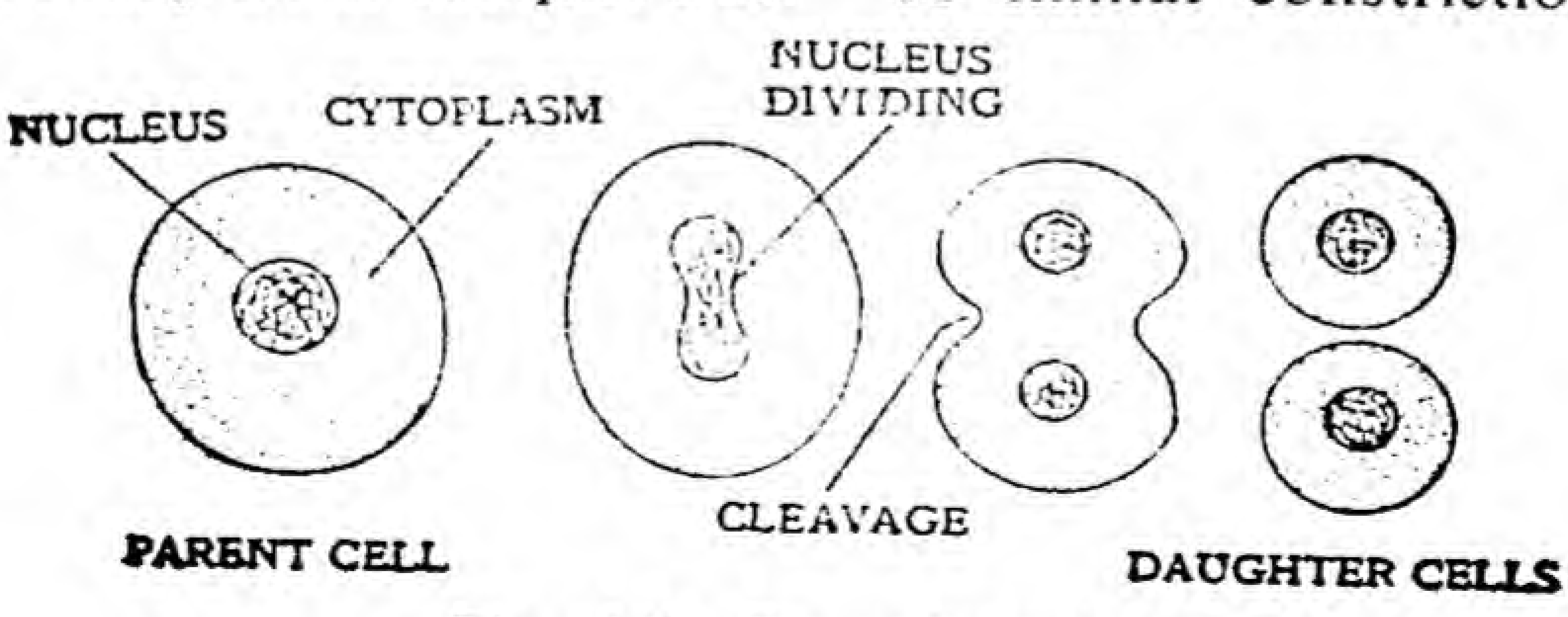


Fig. 4.7. Stages in amitosis

in the cytoplasm and divides the cell into two daughter cells, each with a nucleus. Amitosis is of rare occurrence, probably because it is not a precise method of cell division. It takes place only in the specialised cells (like those in the mammalian cartilage) or in the degenerating cells of the diseased tissues.

II. Mitosis. Mitosis is the common method of cell division. It occurs in all parts of the animal body. It is characterised by the division of the parent cell into two equal-sized daughter cells, each with the same

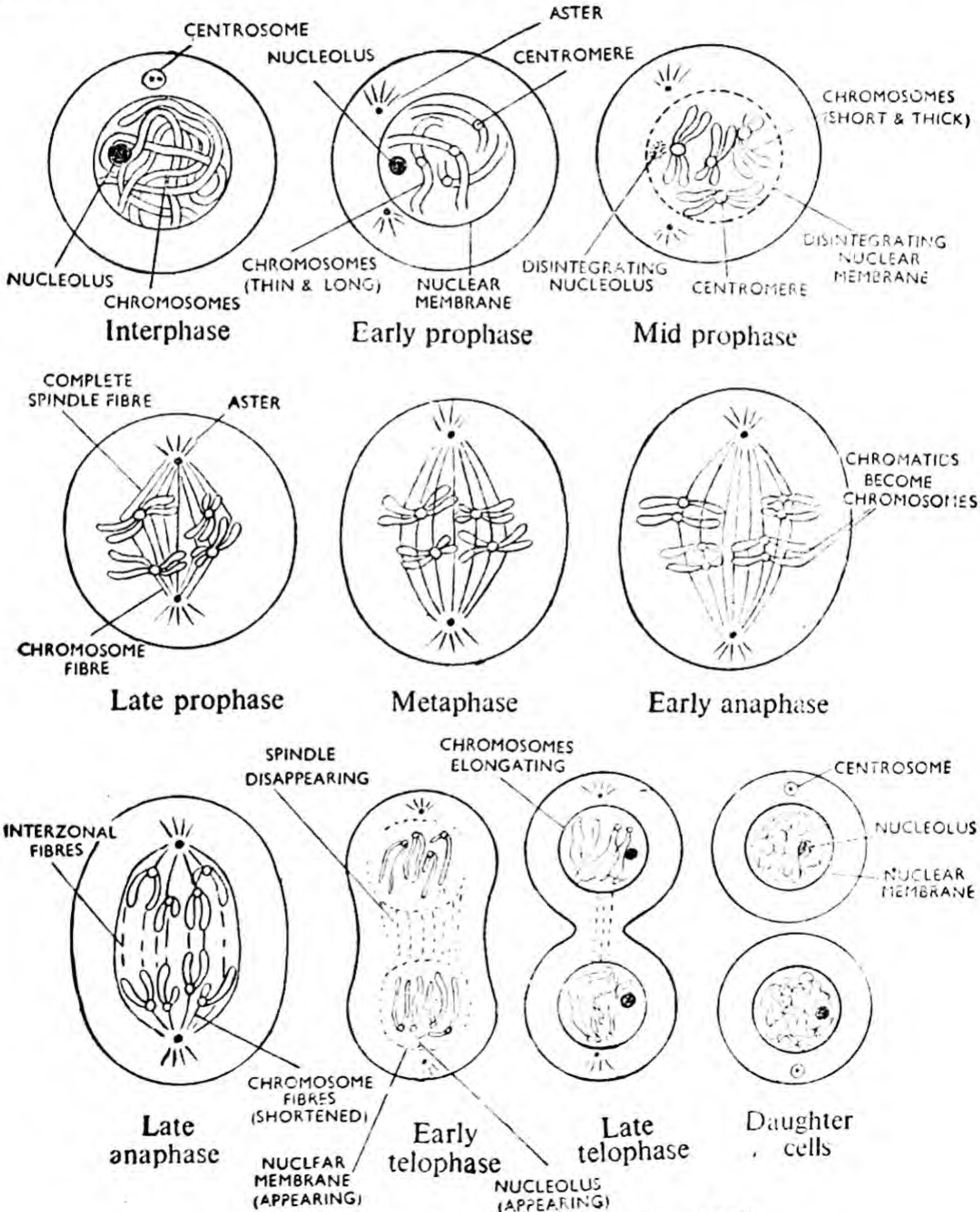


Fig. 4.8. Stages of mitosis in an animal cell

number of chromosomes as the parent cell. It is an elaborate process and involves a series of important changes, both in the nucleus and cytoplasm. It is, therefore, also called the **indirect division**. It lasts on an average from 30 minutes to 3 hours. Though a continuous process, the mitotic cycle is often sub-divided into four stages for convenience of description. These stages are called **prophase, metaphase, anaphase** and **telophase** (Fig. 4.8).

(*i*) **Prophase**. Prophase prepares the nuclear components for actual division and is, therefore, very long and complex. It consumes about 40% of the total time required for mitosis. It may further be divided into three parts : early, middle and late. The prophase is initiated by changes in the centrosome. The centrosphere disappears, setting the two centrioles free in the cytoplasm. The centrioles migrate away from each other towards opposite ends of the cell. As they move, a set of fine radiating fibres appears around each centriole. These fibres are called the **astral rays**. A centriole alongwith its astral rays forms a star-like body, the **astral body** or simply **aster**.

At the time the asters are first formed, a change starts within the nucleus. The chromatin material, which normally appears as a network of fine filaments, begins to condense and assumes the form of long, fine filaments, the **chromosomes**. Each chromosome is double, consisting of two identical components, the **chromatids** or **chromonemata**, joined together at one place by a small body, the **centromere**, and coiled about each other. The chromatids lie in a matrix and may show dark areas called **chromomeres**. With these events, the early part of prophase is over.

The chromosomes become short and thick and their chromatids uncoil. Finally, they attain their characteristic forms and become distinguishable individually. The asters move further away from each other. As the chromosomes become prominent, the nucleolus decreases in size till it disappears altogether, its material getting scattered among the chromosomes. At the same time, the nuclear membrane begins to break down and disperse into the cytoplasm as elements of the endoplasmic reticulum. This completes the middle part of prophase.

As soon as the chromosomes have assumed their final form, fine fibres start extending from the centrioles towards the nucleus. These fibres are known as the **spindle fibres** as they later on assume the form of a spindle. The nuclear membrane continues to break down and finally disappears altogether. This sets the chromosomes free in the cytoplasm. Now the spindle fibres extend to the chromosomes and become attached to them at their centromeres. These spindle fibres are called the **chromosome fibres**. Some spindle fibres extend from pole to pole of the spindle also. These are called the **complete fibres**. With this the prophase ends.

The spindle and the asters at its ends together form the **mitotic figure.** This figure consists of proteins and RNA. It is formed mainly from the cytoplasmic proteins and partly from the nuclear proteins by gelation.

(*ii*) **Metaphase.** Metaphase is short and simple. In this phase, the

chromosomes, which formed disorderly mass at the end of prophase, arrange themselves at the middle (equator) of the spindle in the form of a plate called the **equatorial plate**. The chromosomes are pulled to the equator by the chromosome fibres.

(*iii*) **Anaphase**. Anaphase is also short and simple. The centromere of each chromosome divides into two so that each chromatid comes to possess its own centromere. Almost immediately after this the sister chromatids separate from their respective mates and move towards the opposite poles. The separation of the chromatids begins at the centromeres so that they are pulled into U, V and J shapes. As the chromatids move apart, numerous fine threads appear between them. These are known as the **interzonal fibres** and extend from one chromatid to its former partner. The anaphase ends when all the chromatids have reached the opposite poles. The forces responsible for the movement of the chromatids are not clearly known. Probably, the chromosome fibres contract to pull the chromatids towards the poles, while the interzonal fibres stretch to repel them. The chromatids at each pole are now regarded as the chromosomes.

(*iv*) **Telophase**. Telophase is as long and complex as the prophase. In this phase, nucleus is reconstructed from each group of chromosomes. This involves all the events that occurred in prophase, but in reverse order and direction. Nuclear membrane slowly reforms round each group of chromosomes from the elements of the endoplasmic reticulum. A nucleolus reappears by the reorganization of the nucleolar material, which scattered during prophase. In the meantime, the chromosomes gradually elongate and become slender. Finally, they assemble in the form of irregular threads and granules characteristic of the undividing cell and become indistinguishable. Two nuclei are, thus, formed from one. This division of the nucleus into two daughter-nuclei is called **karyokinesis**. The daughter-nuclei are identical because they are formed from similar chromosomes.

The mitotic figure (astral rays and interzonal, and complete fibres) gradually becomes indistinct and finally disappears by reverting to a sol from a gel condition. Each centriole develops a centrosphere and may divide into two in some cases. Frequently, however, it divides during the interphase (see page 31). In the meantime, a constriction appears around the middle of the cell between the two nuclei. This constriction deepens till the cell completely divides into two cells. The division of the cytoplasm is called **cytokinesis**.

The daughter-cells formed by mitosis enter the interphase in which they grow in size and duplicate their chromosomes. This makes them ready for the next mitosis.

Significance of Mitosis. Mitosis has a manifold significance.

(1) It is a means of growth. The fertilized egg develops into an embryo and finally into an adult by repeated mitotic divisions.

(2) Mitosis results in the division of the parent cell into exactly similar daughter-cells, each with the same number of chromosomes as the parent cell. It, thus, serves to keep the number of chromosomes

equal in all the cells of an individual. For this reason mitosis is also known as the **equational division**.

(3) Mitosis replaces the old worn out cells, thus revitalizing the tissues in the adult animals.

(4) Mitosis plays an important role in reproduction, asexual as well as sexual.

III. Meiosis. Meiosis takes place only in the gonads or reproductive organs during the formation of gametes. In meiosis, the parent cell produces four daughter-cells, each having half the number of chromosomes present in the parent cell. Meiosis is, therefore, also known as the **reduction division**. Reduction is due to the fact that meiosis involves two divisions taking place in rapid succession with the chromosomes duplicating only once. These divisions are called the **first** and the **second meiotic** or **maturation divisions**. The reduced number of chromosomes received by the daughter-cells in meiosis is termed the **haploid number**, while the full number of the parent cell is termed the **diploid number**. Since meiosis occurs during the formation of gametes only, the latter alone have the haploid number of chromosomes. All other cells of the body have the diploid number. The diploid number of chromosomes is fixed for each type of animal. It is 78 for dog, 44 for rabbit and 46 for man. The diploid chromosomes can be arranged in **homologous pairs**, each pair comprising two chromosomes, similar in size, shape and characters. One member of a homologous pair is of maternal origin and the other of paternal origin. They are combined in the zygote by the fusion of male and female gametes.

1. First Meiotic Division (Fig. 4.9.). It comprises four phases : **prophase—1, metaphase—1, anaphase—1**, and **telophase—1**.

Prophase—1. It is quite elaborate and may be sub-divided into four stages : **leptotene**, **zygotene** or **synaptotene**, **pachytene** and **diplotene**.

(*a*) **Leptotene**. In the leptotene stage, the centrosphere disappears, freeing the two centrioles that move away from each other ; astral rays appear around each centriole to form an aster ; and chromatin matter, by condensation, changes into long, fine chromosomes. The chromosomes are double, each consisting of two identical chromatids, which are closely adhered together and are somewhat indistinct.

(*b*) **Zygotene**. In the zygotene stage, the homologous chromosomes (maternal ones and their paternal counterparts) come together and lie side by side in pairs. This coming together of the homologous chromosomes is known as the **pairing of chromosomes** or **synapsis**. The two homologous chromosomes forming a pair twine round each other and are said to form the **bivalent**.

(*c*) **Pachytene**. In the pachytene stage, the paired chromosomes or bivalents become shorter, thicker and more prominent.

(*d*) **Diplotene**. In the diplotene stage, the homologous chromosomes partially separate and their chromatids become distinct. Bivalents, thus, change into groups of four chromatids. Each group of four chromatids is called a **tetrad**. The chromosomes condense further

to acquire their normal form and size. The nuclear membrane and nucleolus disappear, setting the chromosomes (tetrads) free in the cytoplasm. Spindle-fibres extend from the centrioles and join the chromosomes at their centromeres.

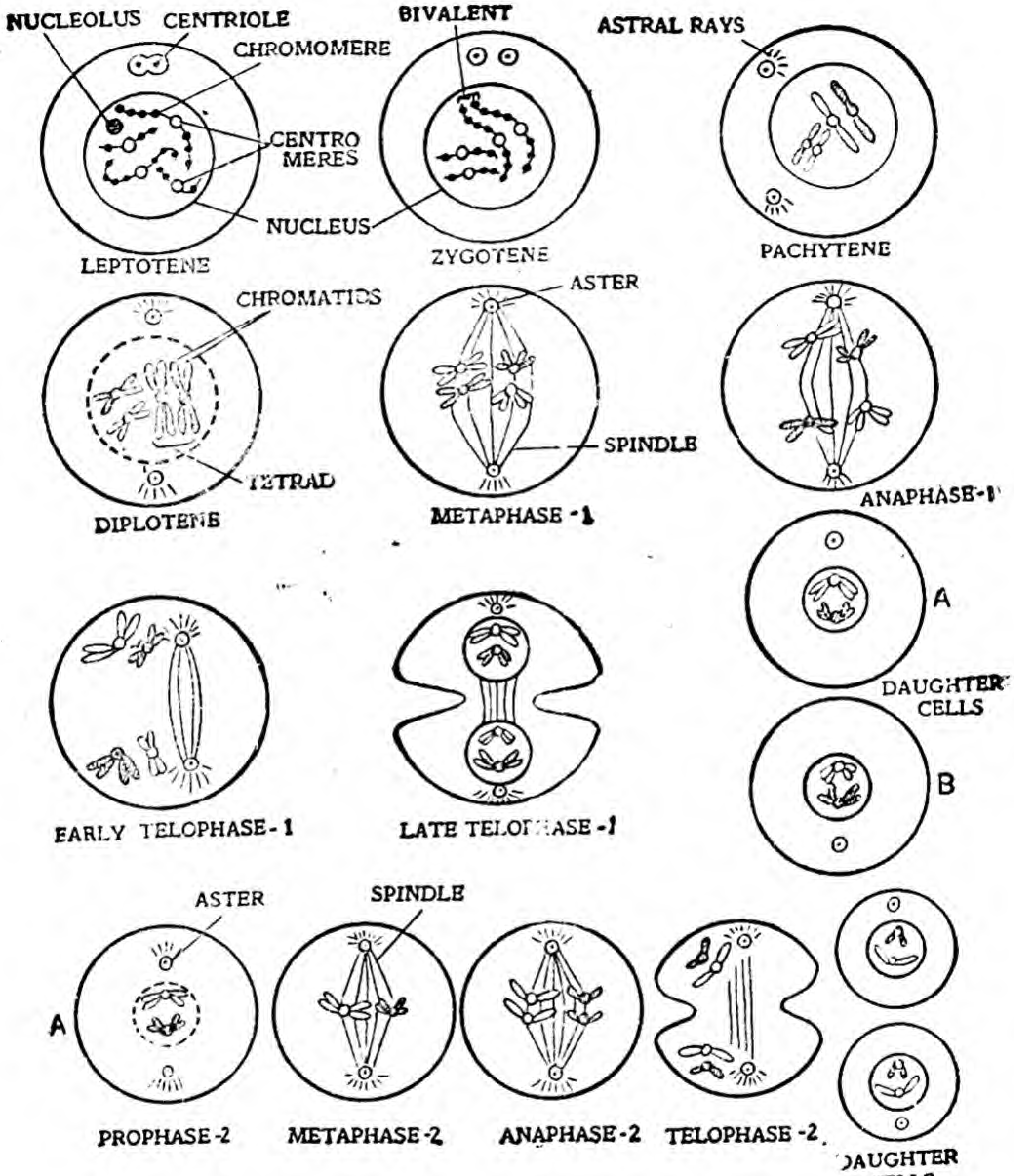


Fig. 4.9. Stages in meiosis in an animal cell. The daughter cell B behaves like the daughter cell A.

Sometimes, there occurs during pachytene or diplotene mutual exchange of corresponding parts of homologous chromosomes of the bivalent. This phenomenon is called **crossing over** and is of great significance in heredity.

Metaphase—1. The chromosomes (tetrads) now arrange themselves

at the equator of the spindle. Each bivalent is attached to the spindle-fibres at two points or centromeres, one belonging to each chromosome of the bivalent. The chromatids of each chromosome are still joined to one another.

Anaphase—1. The two homologous chromosomes of each bivalent move apart and reach the opposite poles of the spindle. Thus, half of the chromosomes which appear in early prophase (leptotene) go to each pole. It is here in the anaphase that the real reduction in the number of chromosomes occurs. Each chromosome at the poles consists of two chromatids joined together at the centromere.

Telophase—1. The chromosomes at each pole now form a nucleus with a nuclear membrane and a nucleolus. The spindle and the astral rays gradually disappear. The cytoplasm constricts into two daughter-cells, each with one nucleus. The nucleus of each daughter cell has received only one chromosome from each homologous pair or bivalent. Thus, it has half the number of chromosomes present in the parent cell.

2. Second Meiotic Division. It also comprises four stages: **prophase—2, metaphase—2, anaphase—2** and **telophase—2.**

Prophase—2. Centrioles become free, move apart and develop astral rays to form asters. The chromosomes, each comprising two chromatids joined by centromere, become visible. They are set free by disappearance of the nuclear membrane. Nucleolus goes out of existence. Spindle-fibres are formed between the centrioles and centromeres of chromosomes.

Metaphase—2. The chromosomes take up positions at the equator of the spindle. The two chromatids of each chromosome are still joined by a centromere.

Anaphase—2. The centromeres divide and the chromatids start moving away from each other. Ultimately, they reach the poles of the spindle and are called the chromosomes.

Telophase—2. The group of chromosomes at each pole gets enveloped by a nuclear membrane. The nucleolus appears. Astral rays and spindle are lost. Cytoplasm constricts to form two daughter-cells, each with the haploid number of chromosomes.

The second meiotic division may follow the first immediately or there may be a brief interphase between the two. In the former case, the telophase of the first meiotic division is not completed and the prophase of the second meiotic division is almost eliminated except the formation of a spindle. The telophase chromosomes of the first division start metaphase of the second division.

Significance of Meiosis. Meiosis has two main aspects, both of which have a great significance. These are reduction in chromosome number and introduction of variations.

(1) **Reduction of Chromosome Number.** Meiosis reduces the number of chromosomes from the diploid to the haploid condition. This

helps in keeping the number of chromosomes constant from generation to generation. Meiosis forms haploid gametes, which unite in sexual reproduction, thus restoring the original diploid number characteristic for the species. If there is no meiosis and the gametes are formed by mitosis, the number of chromosomes in each new generation will become double of that in the previous generation.

(2) **Variations.** Meiosis provides a chance for the establishment of new combinations of chromosomes. This brings about **variations** and through them **evolution**. The new combinations are due to the random distribution of chromosomes between the daughter cells and to the crossing-over.

TABLE 2.

Comparison of Mitosis and Meiosis

Mitosis	Meiosis
1. It occurs in all parts of the body.	1. It occurs only in the gonads.
2. It involves a single division, resulting in two daughter cells only.	2. It involves two divisions that occur in quick succession, resulting in four daughter cells.
3. Prophase is comparatively short and simple.	3. Prophase—1 is very long and elaborate, comprising four sub-phases.
4. Prophase chromosomes appear double from the very start. Their chromomeres are indistinct.	4. Prophase—1 chromosomes do not appear double in the beginning and show prominent chromomeres.
5. There is no pairing of homologous chromosomes, hence no chance of crossing-over.	5. Homologous chromosomes pair and may undergo crossing-over.
6. Anaphase involves separation of chromatids after splitting of centromeres joining them.	6. Anaphase—1 involves separation of homologous chromosomes with centromeres remaining intact. The centromeres split and chromatids move apart in anaphase—2.
7. Daughter cells are diploid and resemble the parent cell.	7. Daughter cells are haploid and do not resemble the parent cell, which is diploid.
8. Mitosis brings about growth and replaces old worn-out cells.	8. Meiosis maintains the chromosome number from generation to generation.

Interphase

When not dividing, the cell is said to be in the **interphase**. During this period, very important processes occur. These include duplication of chromosomes, doubling of centriole, synthesis of protein for the

mitotic figure and storage of energy for the next division. The duplication of chromosomes does not occur by division as held earlier. Instead, it is brought about by **replication**, *i.e.* synthesis of an exact duplicate of each chromosome. The invisible interphase activities make the cell ready for division.

An interphase cell is sometimes described as the "resting cell." This, however, is quite inappropriate as the cell does not rest even when it is not dividing. Though it does not show changes characteristic of a dividing cell, it is still carrying on the various activities of life and its chromosomes are in a state of replication.

Gametogenesis

The body of a **metazoan** or multicellular animal consists of two types of cells : the **somatic** or **body-cells** and the **germinal cells**. The somatic cells are very numerous and form all the parts of the body except the gonads. They are concerned only with the life of an individual animal and for this they carry on the vegetative functions of the body. The germinal cells, on the contrary, are fewer and are restricted only to the sex-organs or gonads. They are meant for the propagation of the species and for this they produce the gametes. The formation of the gametes from the primordial germ cells of the gonads is called **gametogenesis**. As the gametes are of two types, namely, the **spermatozoa** or **sperms** or the **male gametes** and the **ova** or **female gametes**, gametogenesis is also of two types. These are **spermatogenesis** or the formation of sperms and **oogenesis** or the formation of ova. Both processes are basically similar, though minor differences exist. Both involve three important phases : **multiplicative phase** in which the immature cells multiply by mitosis, **growth phase** in which the immature cells grow and **maturation phase** in which meiosis occurs.

Spermatogenesis (Fig. 4.10). The primordial or undifferentiated cells of the testes are called the **spermatogonia**. The spermatogonia have diploid number of chromosomes, say four in a particular animal. The spermatogonia increase their population by repeated mitotic divisions so that each newly-formed spermatogonium possesses the same number of chromosomes, *i.e.* four. Finally, the spermatogonia increase in size and are termed the **primary spermatocytes**. The primary spermatocytes undergo first meiotic division and produce **secondary spermatocytes**, each of which contains half or haploid number of chromosomes, *i.e.* two. The secondary spermatocytes undergo the second meiotic division and produce **spermatids**. Each spermatid continues to possess the haploid number of chromosomes, which is two in this case. The spermatids gradually modify themselves into **spermatozoa** or **male gametes**, which are also haploid. The transformation of spermatids into spermatozoa is known as **spermateleosis**. Each primary spermatocyte, thus, produces four spermatozoa. Each spermatozoon consists of a **head** having the nucleus and a long vibratile **tail**. It swims by the vibrations of its tail in a fluid medium in search of the ovum or female gamete.

Oogenesis. (Fig. 4.10). The differentiated germ cells of the ovary are called oogonia. Each oogonium possesses diploid number of chromosomes. The oogonia divide mitotically to multiply their

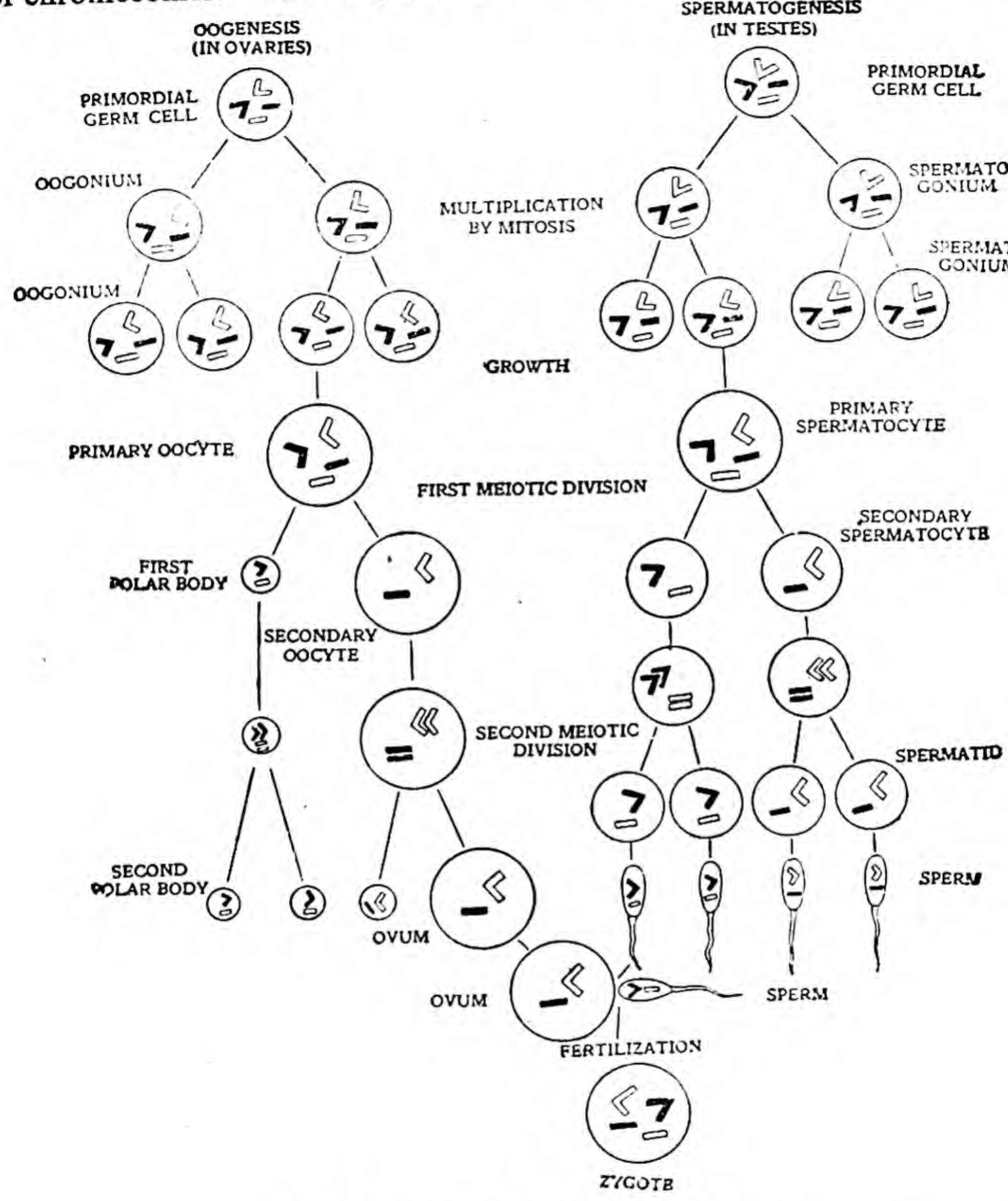


Fig. 4.10. Stages in gametogenesis

number. Each oogonium prepares itself for the formation of an ovum. It increases in size due to the deposition of yolk granules in its cytoplasm. It is now called the **primary oocyte**. Like the primary spermatocyte, the primary oocyte also undergoes first meiotic division and produces **two cells**. The division is, however, very unequal and one of the two daughter cells is extremely small, while the other is almost as large as the primary oocyte itself. The large cell is called the **secondary oocyte**

and the small cell is known as **the first polar body.** Both have the haploid number of chromosomes. The secondary oocyte now undergoes second meiotic division and forms a large cell or **ovum** and a small cell or the **second polar body.** The first polar body also divides into two. One primary oocyte, therefore, forms, after the meiotic division, one mature ovum and three polar bodies. The polar bodies have no function and disintegrate. The ovum retains the whole of the cytoplasm and the food of the primary oocyte in it for the nourishment of the future embryo.

Usually, the ovum contains a lot of food in it and is called **lecithal.** In the mammals, however, the ovum is free from the food and is called **alecithal.** In the lecithal ovum, the food may be uniformly distributed all over (*e.g. Amphioxus*) or localised at one end (*e.g.* chick) or deposited at the centre (*e.g.* insects). These conditions are described by the terms **homolecithal, telolecithal** and **centrolecithal** respectively.

Fertilization

Fertilization is the union of the mature spermatozoon and the ovum. The cell formed as a result of this union is called the **zygote** or the fertilized ovum. The spermatozoon enters the ovum through the **reception cone**, which is a small protuberance on its surface. The entry of the spermatozoon is probably brought about by the engulfing action of the ovum. As soon as the sperm has entered the ovum, certain changes take place in the ovum to check the entry of more sperms. Sometimes, however, additional sperms may enter the ovum but only one fuses with the ovum. This phenomenon is called **polyspermy** and occurs in the ova with much yolk *i.e.* hen's egg. The sperm may enter the immature ovum but the two will not fuse until the maturation of the ovum is completed.

The nucleus of the sperm is called **male pronucleus.** Similarly, the nucleus of the ovum is known as the **female pronucleus.** In the act of fertilization, the tail of the sperm does not take any part and degenerates. The male and the female pronuclei fuse together and form the **zygote nucleus** or **synkaryon.** The real fertilization is, thus, the union of the male and female pronuclei. The fusion of the two haploid pronuclei yields a zygote nucleus with diploid number of chromosomes characteristic for the species.

Types of Fertilization. Usually, the animals are **unisexual** or **dioecious** and fertilization combines gametes from two different individuals. This is called **cross-fertilization.** In a few **bisexual** or **monoecious** animals, the same individual produces male and female gametes, which are capable of fertilization. This is called **self-fertilization.** In certain animals (many invertebrates, some marine fishes, amphibians, etc.) both ova and sperms are shed into water, where fertilization occurs. This is known as the **external fertilization.** In others, fertilization takes place inside the body of the female and is known as the **internal fertilization.** In such cases, the sperms are shed by the male within the reproductive tract of the female during **copulation** or sexual union.

Significance of Fertilization. Fertilization has a three-fold importance.

(1) It stimulates the ovum to develop into a new individual by repeated mitotic divisions. This development of an offspring from the zygote is called **sexual reproduction**.

(2) Fertilization restores the diploid number of chromosomes in the zygote by the fusion of two haploid gametes.

(3) Fertilization combines characters of two parents, thus, introducing variations.

TEST QUESTIONS

1. What is a cell ? Describe the structure of a generalized animal cell.
2. What is protoplasm ? Give an account of the physical and chemical nature of protoplasm.
3. How do mitosis and meiosis differ from each other ?
4. Explain the following terms :—Cell Theory, Fertilization, Spermatogenesis, Oogenesis, Synapsis, Amitosis, Cytokinesis, Gamete, Homologous Chromosomes.
5. Give an account of mitosis in an animal cell.
6. Discuss the significance of meiosis. Where and how does this process occur ?
7. Give an account of spermatogenesis or oogenesis.
8. Write a brief note on DNA.

CHAPTER 5

Histology

Histology is the study of the microscopic structure of the tissues and organs of the body. It may also be called **microscopical anatomy. The** knowledge of histology is essential to understand the **activities of** complex animals, particulary the vertebrates.

TISSUES

A **tissue** is a group of cells specialized to perform one or more functions along with any intercellular material secreted by them. There are several types of animal tissues. They are usually grouped into four main classes : **epithelial tissues, muscular tissues, connective or supportive tissues** and **nervous tissues.**

I. Epithelial Tissues

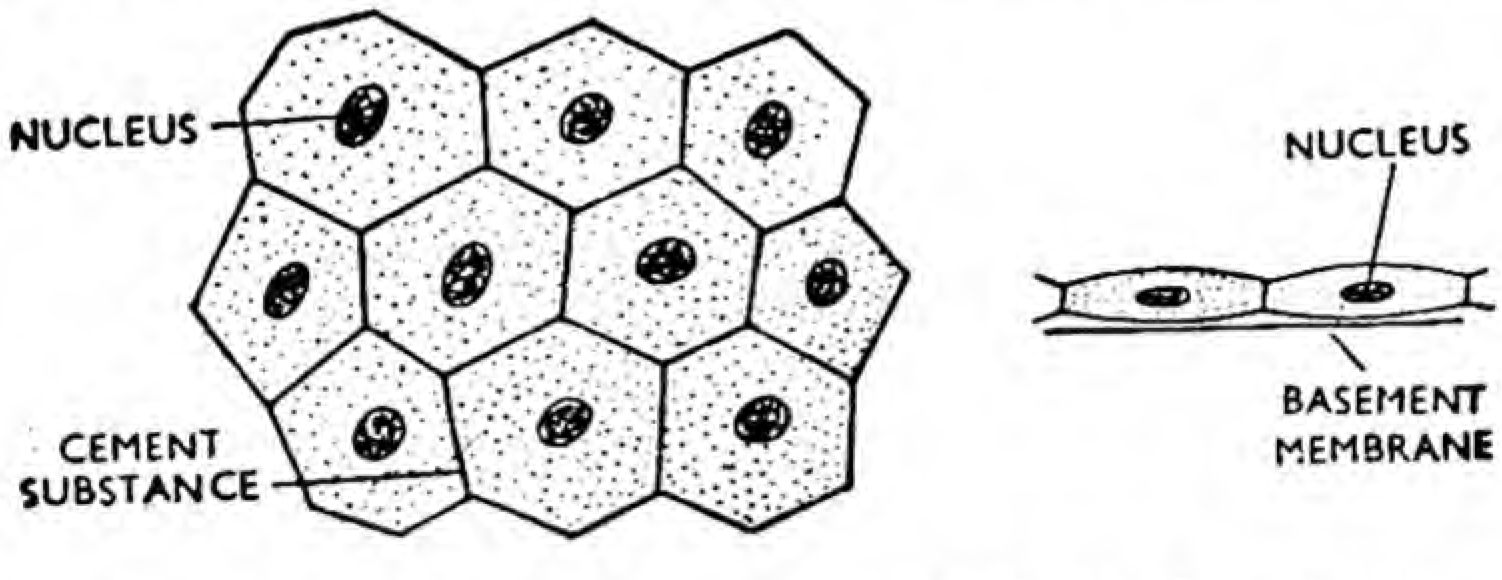
The epithelial tissues consist of cells compactly arranged to form continuous sheets. The cells are held together by a thin layer of self-secreted intercellular cement-substance and rest on a delicate non-cellular (gelatinous) basement membrane. The epithelia generally lack blood-vessels but still have a good power of generation and repair after injury. They receive useful materials and eliminate waste products by diffusion. The epithelia cover the surfaces and line the cavities. They primarily protect the underlying tissues from mechanical injuries, desiccation, entry of germs and harmful chemicals. The surface epithelia produce many useful structures like scales of reptiles, birds and mammals, feathers, hair, claws, nails, hoofs and horns. The epithelia lining the cavities give rise to glands that provide valuable secretions. Besides these, the epithelia are also responsible for absorption, and sensation.

Epithelia were the first tissues to evolve in the animal kingdom. They are also the first to appear, as ectoderm and endoderm, in the development of the individual.

There are two main types of epithelia : **simple** and **compound.** The simple epithelia are one-cell deep and cover moist surface where there is little wear and tear by friction. The simple epithelia are of five types according to the form and structure of their cells : **squamous, cuboidal, columnar, ciliated** and **germinal.** The compound epithelia are

more than one-cell deep and cover the surface where constant replacement of cells is needed due to rapid wear and tear by friction. The common forms of compound epithelia are the **stratified epithelium and transitional epithelium.**

1. Squamous Epithelium. The squamous epithelium (Fig. 5.1) consists of flat, disc-like cells closely fitted together like the tiles of a floor. This



A—Surface view **B—Vertical section**
Fig. 5.1. Squamous epithelium

epithelium is, therefore, also known as the pavement epithelium. The cells are slightly thicker near the centre. The thicker part contains the nucleus, which is also flattened like the cell. The squamous epithelium lines the Bowman's capsules in the kidneys, blood-vessels and coelom. In the Bowman's capsules, the cell outlines are roughly polygonal in surface view. In the blood-vessels and the coelom, the cell outlines are wavy in surface-view. The squamous epithelium with wavy cell outlines is called **tesselated epithelium** (Fig. 5.2). The outermost layer of the skin, which is periodically cast off by frog as thin sheets, is often regarded as the squamous epithelium. This layer is, in fact, a part of the compound epithelium and is not an epithelium in itself.

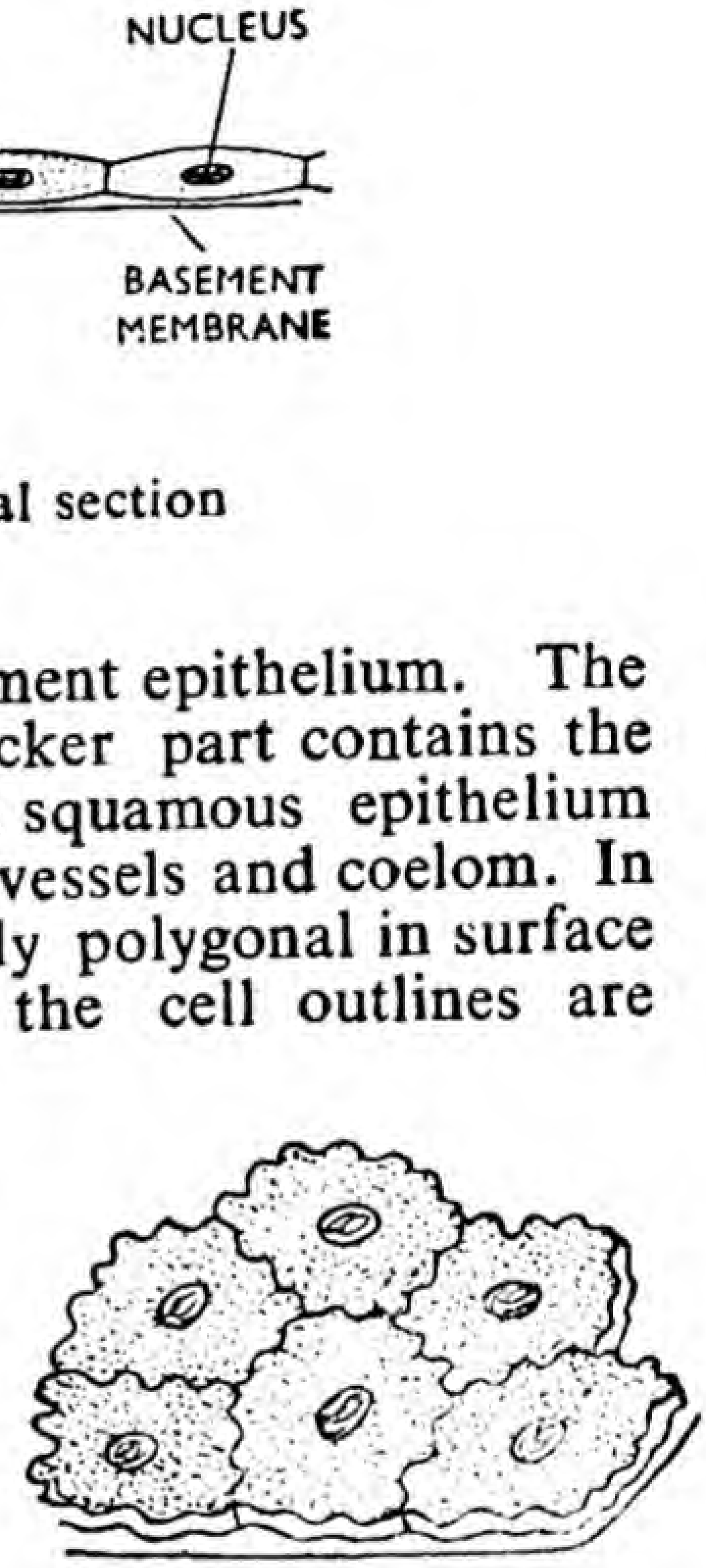


Fig. 5.2. Tesselated epithelium

2. Cuboidal Epithelium. The cuboidal epithelium (Fig. 5.3) consists of cubical cells. The cell outlines are polygonal in surface-view. The nucleus is rounded and lies in the centre of the cell. The cuboidal epithelium lines the urinary tubules of the kidney.

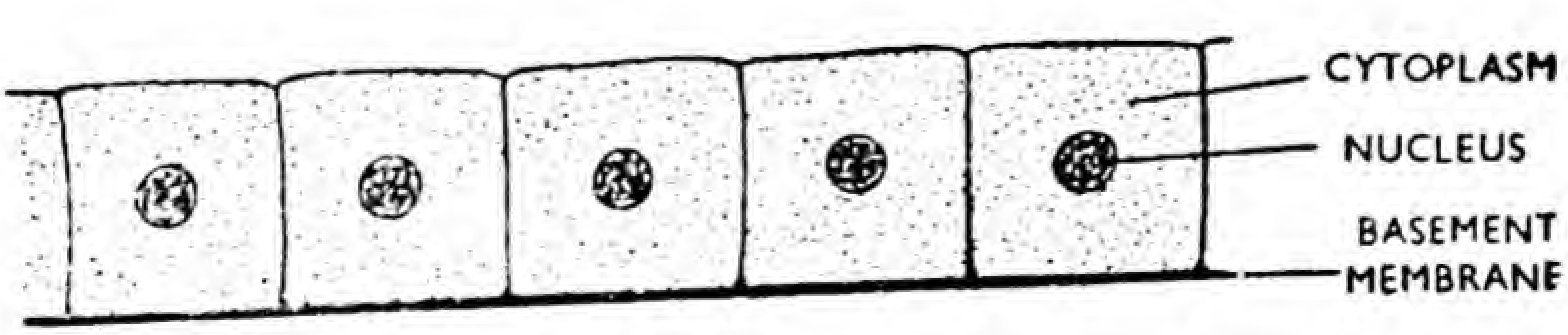


Fig. 5.3. Cuboidal epithelium

3. Columnar Epithelium. The columnar epithelium (Fig. 5.4) consists of tall cells resembling pillars or columns. The cell outlines are

polygonal in surface-view. The nucleus is elongated along the long axis of the cell and has a variable position.

The columnar epithelium is of two types : **glandular and sensory.** The glandular columnar epithelium (Fig. 5.4) lines the stomach and

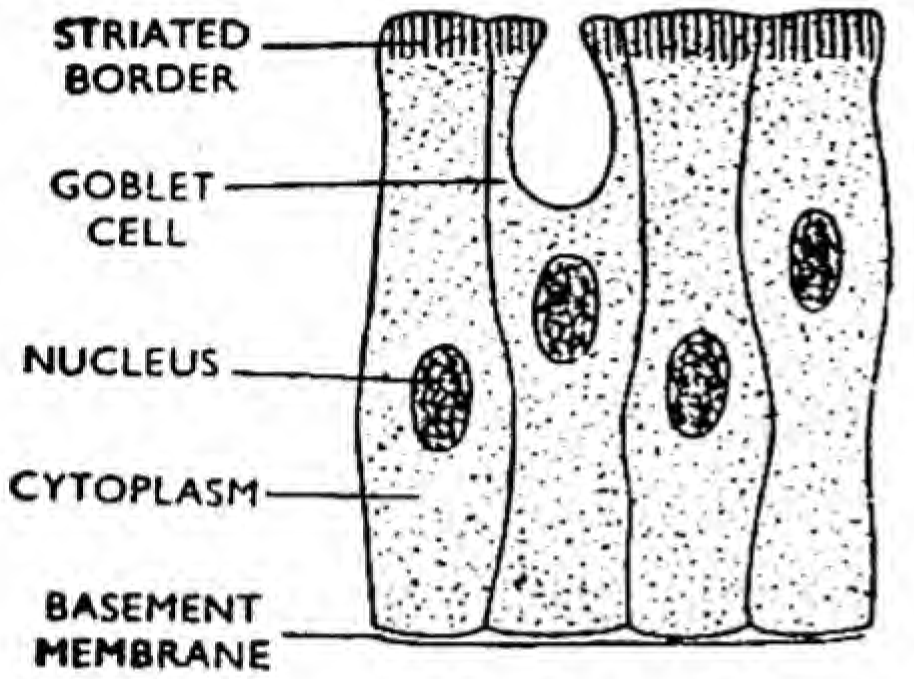


Fig. 5.4. Columnar epithelium

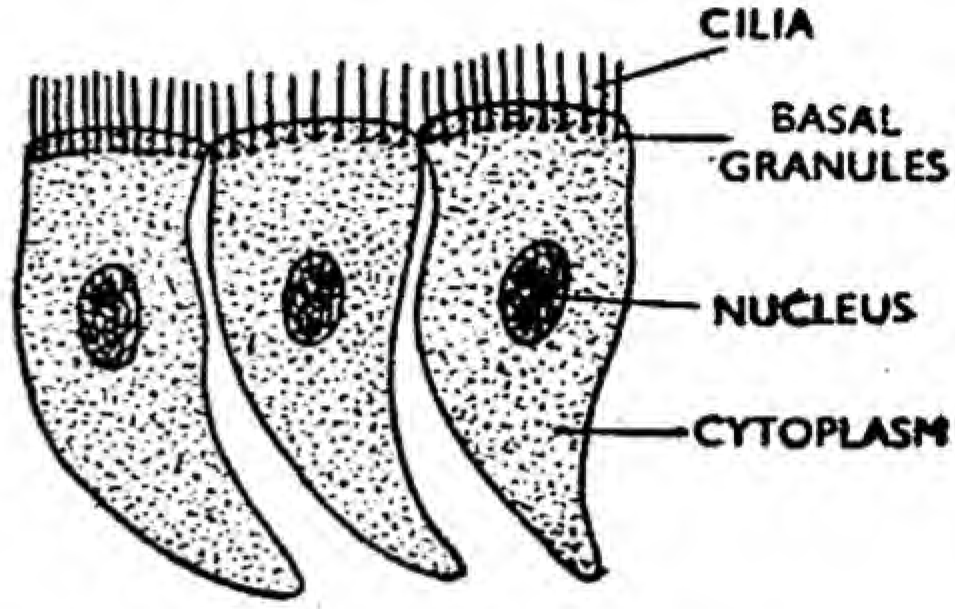


Fig. 5.5. Ciliated epithelium

the intestine. Its cells are specialized for the secretion of digestive juices. In the small intestine, the columnar cells often have **striated border** at the free surface for aiding in absorption. The sensory columnar epithelium lines the nasal sacs. Its cells have fine sensory hair at the free surface and are specialized for receiving external stimuli.

4. Ciliated Epithelium. The ciliated epithelium (Fig. 5.5) consists of columnar or cuboidal cells bearing fine vibratile processes, the **cilia,** at the free surface. The ciliated epithelium with columnar cells lines the bucco-pharyngeal cavity of frog. The ciliated epithelium with cuboidal cells is found in certain parts of the urinary tubules, where it serves to keep the urine moving.

5. Germinal Epithelium. The germinal epithelium is found in the gonads. It gives rise to the sex cells or gametes for sexual reproduction.

6. Stratified Epithelium The stratified epithelium (Fig. 5.6) consists of many layers of cells, which vary in form in different layers. The innermost layer has columnar cells and rests on a basement membrane. This is called the **germinative layer.** The cells of this layer go on dividing by mitosis to produce new cells. The latter are gradually pushed upwards and become progressively flattened and dead. The outermost cornified layer has flat dead cells and is periodically sloughed off by friction. The stratified epithelium forms the outer part or **epidermis** of the skin. Here it serves to check evaporation.

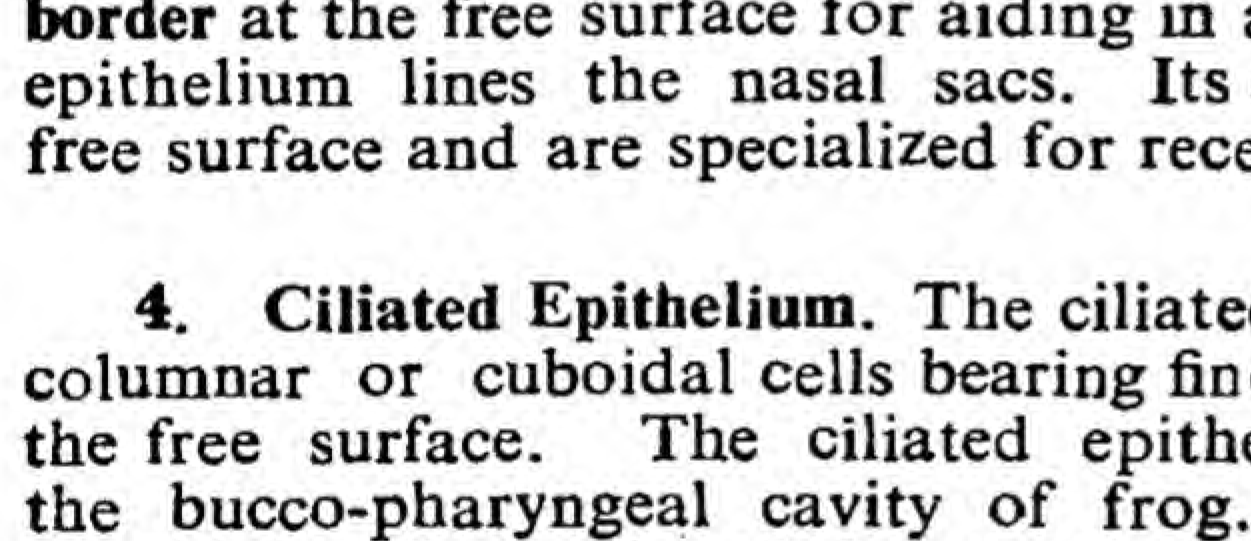


Fig. 5.6. Stratified epithelium

7. Transitional Epithelium. The transitional epithelium differs from the stratified epithelium in that its surface cells are less flattened and uncornified. This epithelium lines urinary bladder.

II. Muscular Tissues

The muscular tissues mostly develop from the mesoderm. They consist of greatly elongated and highly contractile cells known as the **fibres**. The adjacent fibres are held together by connective tissue, there being no intercellular substance. Each fibre contains fine longitudinal fibrils, the **myofibrils**, lying in the cytoplasm, called the **sarcoplasm**. A muscle fibre is sometimes bounded by a specialized membrane, the **sarcolemma**. The muscular tissues are responsible for the movements of the various parts of the body and also for locomotion.

There are three kinds of muscles : **visceral or smooth, skeletal** or **striated** and **cardiac.**

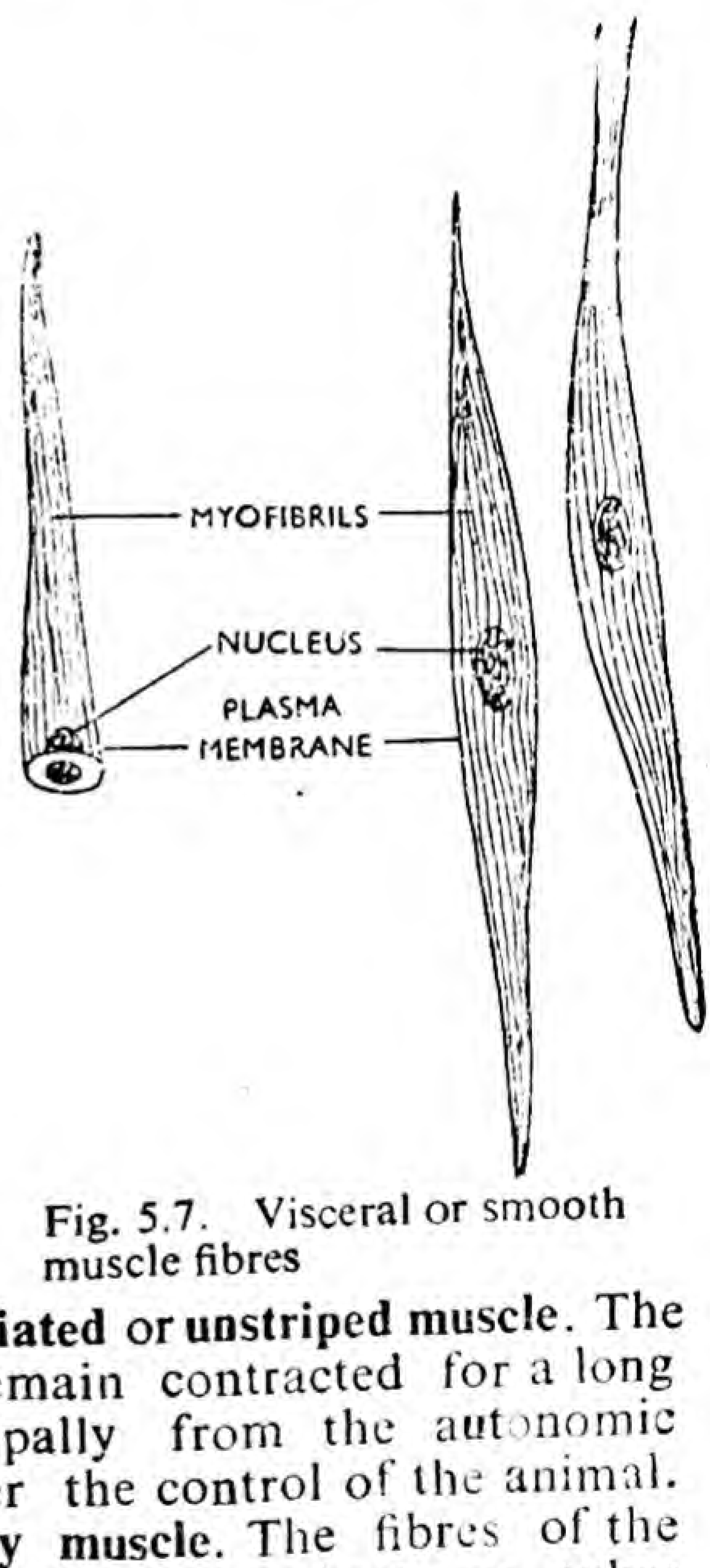
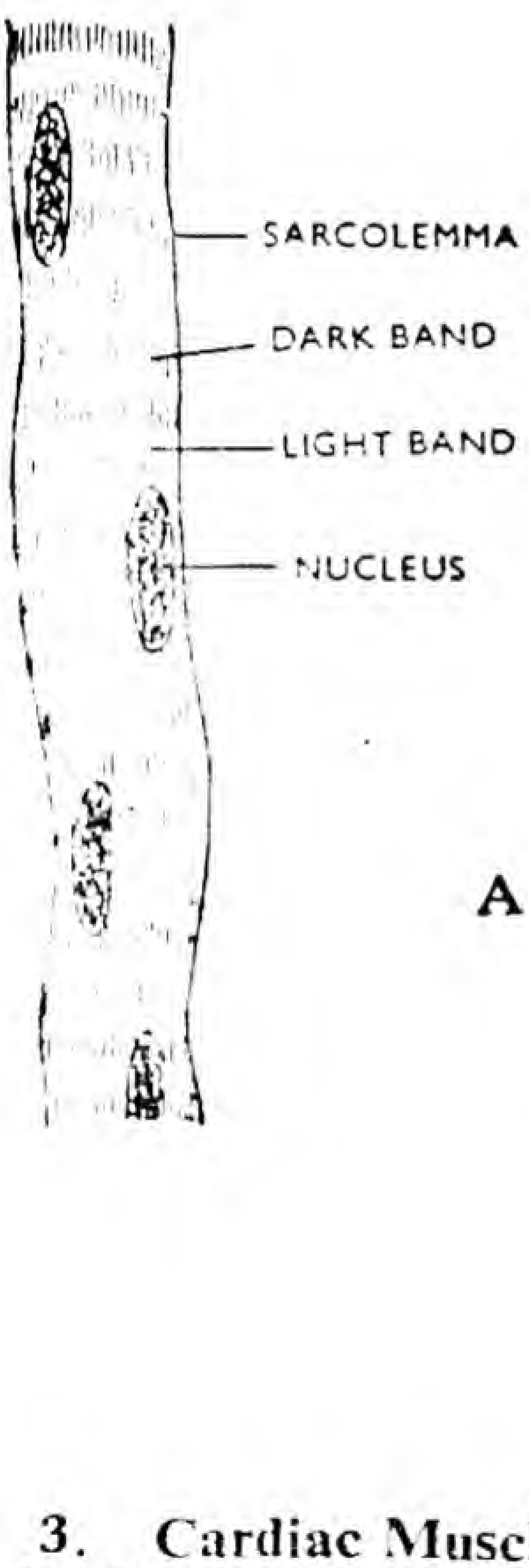


Fig. 5.7. Visceral or smooth muscle fibres

1. Visceral or **Smooth Muscle** (Fig. 5.7). The visceral or smooth muscle is found in the wall of the gut, blood-vessels and urino-genital tract. It also occurs in the iris of the eye and dermis of the skin. It consists of long spindle-shaped fibres, each containing a single oval nucleus in the middle. There is no sarcolemma, the fibre being bounded merely by its plasma membrane. The cross-striations, characteristic of the skeletal muscle, are absent, hence **smooth, unstriated** or **unstriped muscle**. The visceral muscle contracts slowly, but can remain contracted for a long time. It is innervated by nerves principally from the autonomic nervous system. Its contraction is not under the control of the animal. It is, consequently, also called the **involuntary muscle**. The fibres of the visceral muscle are generally arranged in continuous sheets or tubes round the organs in which they occur.

2. Skeletal or Striated Muscle. The skeletal muscle (Fig. 5.8 A and B) is found in the body-wall and limbs. It also occurs in the tongue, pharynx and beginning of the oesophagus. It consists of long, cylindrical fibres with blunt ends. Each fibre is bounded by an elastic sheath or sarcolemma and contains many nuclei. The nuclei are situated just beneath the sarcolemma. The myofibrils show alternating dark and light cross-bands or stripes, hence striated or striped muscle. Every dark band has a light zone in it and every light

band likewise has a dark line in it. The part of the fibre between the dark lines of the two successive light bands is considered as the structural unit of the striated muscle and is called the sarcomere. The skeletal muscle contracts rapidly but cannot maintain contraction for a long time, since it soon gets fatigued. It is innervated by motor nerves from the brain and spinal cord and its contraction is under the control of the animal. It is, therefore, also called the **voluntary muscle.** The fibres of the skeletal muscle are arranged in separate bundles, the **fasciculi**, which are attached to some part of the skeleton by their ends.



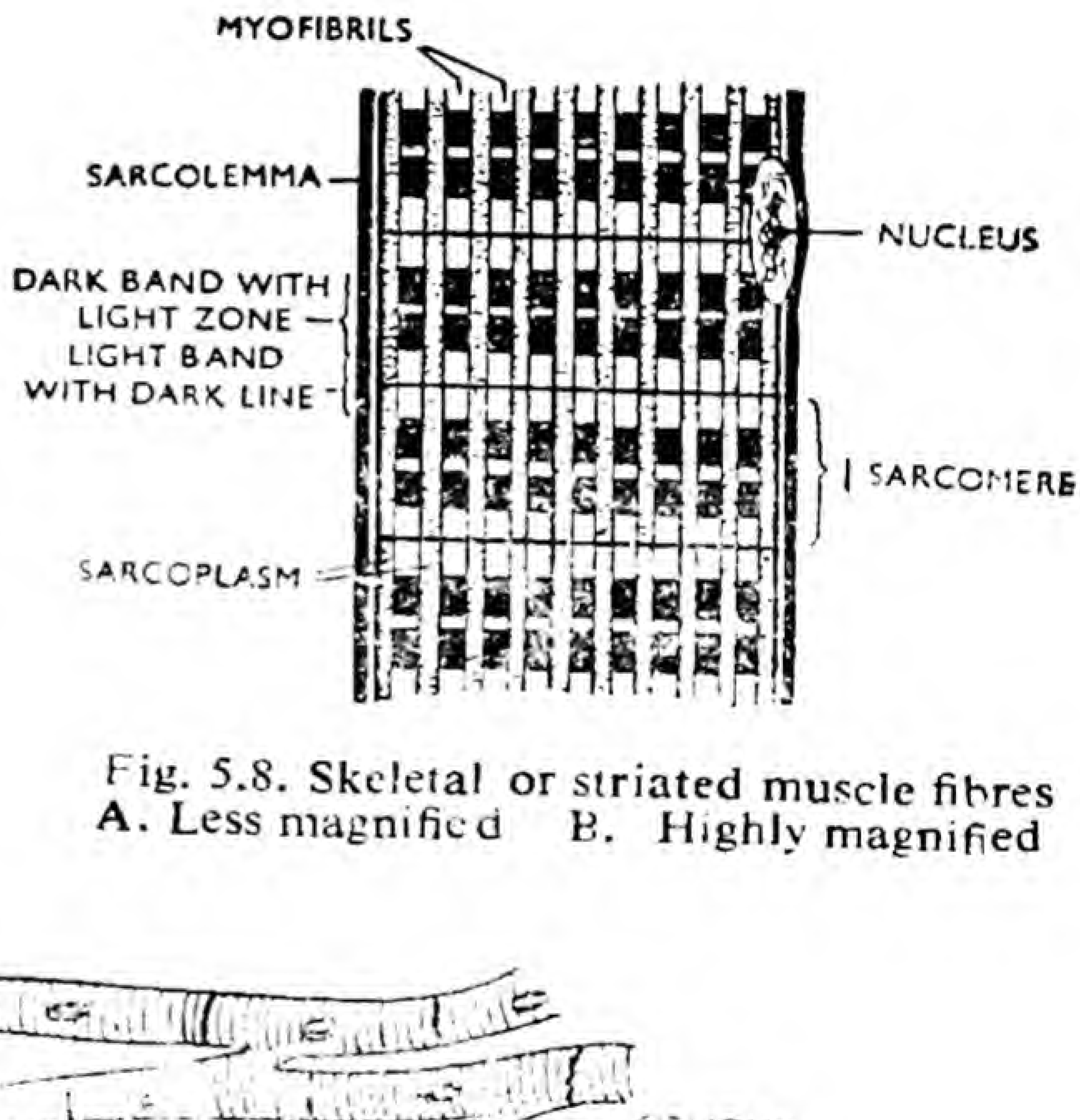


Fig. 5.8. Skeletal or striated muscle fibres
A. Less magnified B. Highly magnified

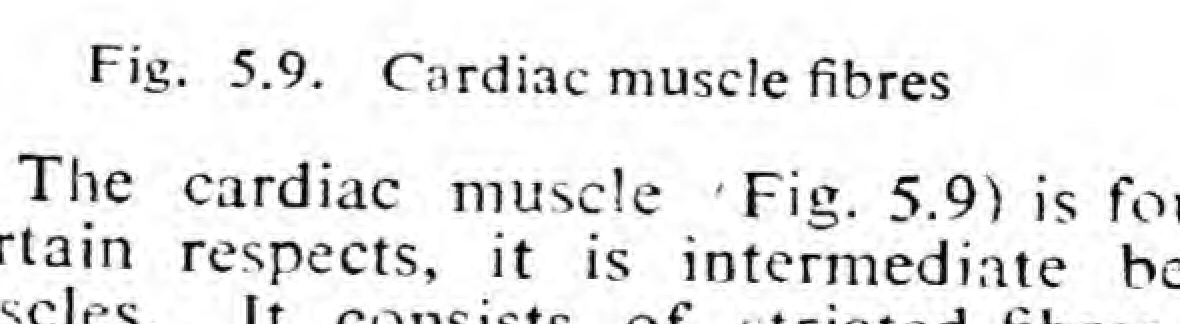


Fig. 5.9. Cardiac muscle fibres

3. **Cardiac Muscle.** The cardiac muscle (Fig. 5.9) is found in the wall of the heart. In certain respects, it is intermediate between the smooth and striated muscles. It consists of striated fibres, which are branched and interconnected to form a contractile network. This structure accounts for the rhythmic contractions characteristic of heart-muscle. The fibres are uninucleate and lack the sarcolemma. The nuclei are located in the central region of the cells. Here and there the fibres have thick cross-bands, the **intercalated discs**. The latter have recently been shown by the electron microscope to be double membranes. They are, therefore, interpretted as modified cell

*which never gets tired.

membranes. The cardiac muscle contracts rhythmically and is indefatigable.* Its contraction is not under the control of the will.

The important differences between the three types of muscle fibres are summarised below in the Table 3.

TABLE 3

Comparison of Muscle Fibres

Striped	Unstriped	Cardiac
1. Occur in the body-wall, limbs, tongue, pharynx and beginning of oesophagus.	1. Occur in visceral wall, iris of the eye and dermis of the skin.	1. Occur in the heart wall.
2. Form bundles that are attached to skeleton by ends.	2. Form sheet or tubes in the visceral wall.	2. Form a continuous network by branching and anastomosis.
3. Very long and cylindrical with blunt ends.	3. Long and spindle-shaped with tapering ends.	3. Short and cylindrical with truncate ends.
4. Bounded by distinct sarcolemma.	4. Bounded by plasma membrane, there being no sarcolemma.	4. Bounded by plasma membrane, no sarcolemma.
5. Syncytial, nuclei just within the sarcolemma.	5. Uninucleate, nucleus at the centre.	5. Uninucleate, nucleus at the centre.
6. Myofibrils large and prominent, show alternating light and dark cross bands, hence striped.	6. Myofibrils indistinct and do not have light and dark bands, hence unstriped.	6. Myofibrils distinct and with alternating light and dark bands.
7. Contract quickly but cannot maintain contraction for a long time, hence soon get fatigued.	7. Contract slowly but can remain contracted for a long time, are not fatigued.	7. Contract quickly and rhythmically, indefatigable.
8. Innervated by nerves from central nervous system.	9. Innervated by nerves from autonomic nervous system.	8. Innervated by nerves from autonomic nervous system.
9. Voluntary.	9. Involuntary.	9. Involuntary.

III. Connective Tissues

The connective tissues develop from the mesoderm of the embryo. They consist of variously-shaped cells scattered in a large amount of intercellular or ground substance known as the **matrix**. The matrix is a non-living material and is usually secreted by the connective tissue-

cells themselves. The chief functions of the connective tissues are to bind the different tissues together, to store fat, to form a supporting frame-work, to provide a hard surface for muscle attachment, to protect the organs, to transport materials from one place to another in the body and to defend from the foreign bodies. There are three types of connective tissues, namely, (*i*) the connective tissues proper, (*ii*) the skeletal tissues and (*iii*) the vascular tissues.

1. Connective Tissues Proper. The connective tissues proper are characterized by the presence of fibres in the matrix. They serve to bind the tissues together and to form protective membranes round the organs. They are of several types : **areolar tissue, adipose tissue, white fibrous tissue, yellow elastic tissue** and **reticular tissue.**

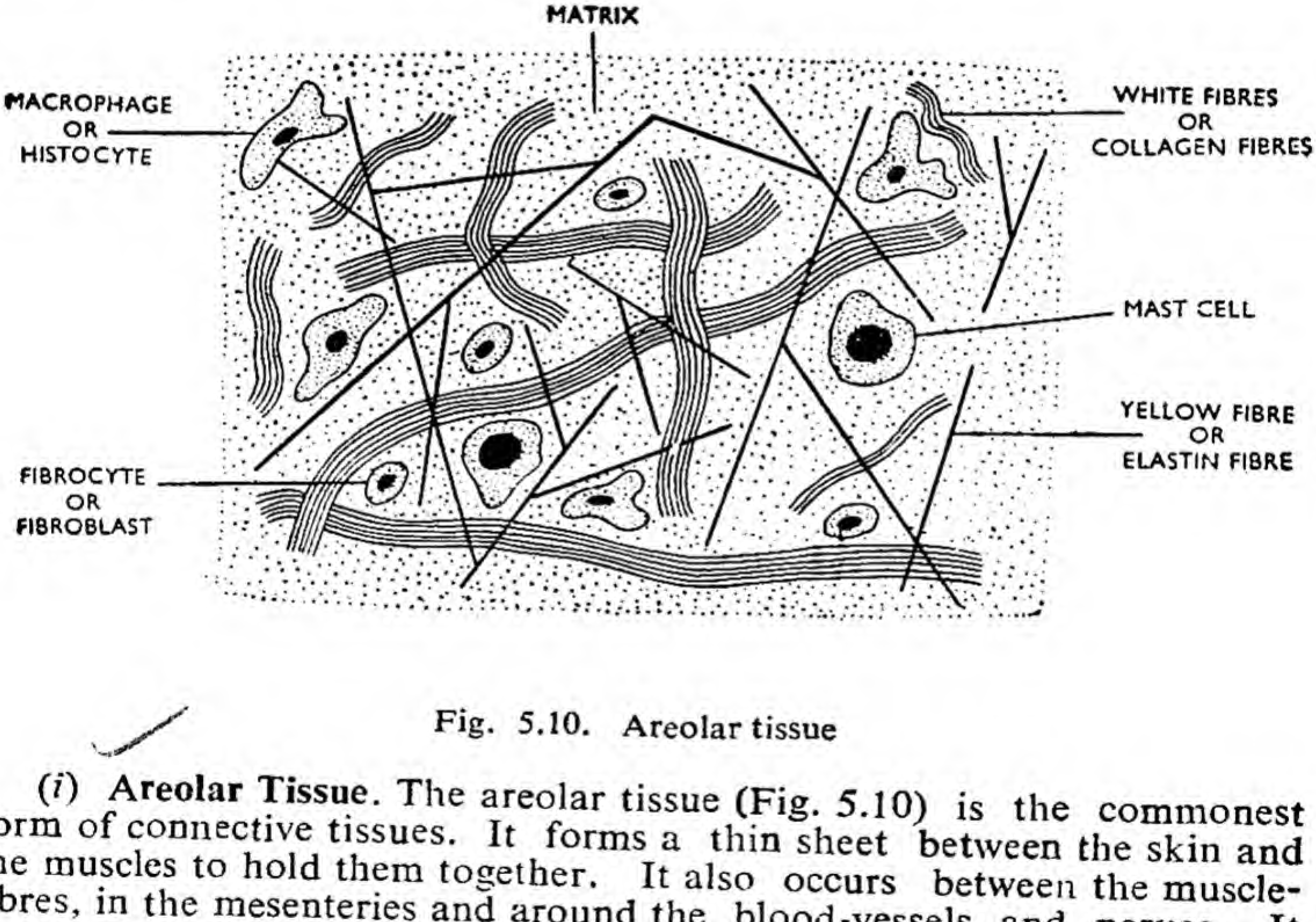


Fig. 5.10. Areolar tissue

(*i*) **Areolar Tissue**. The areolar tissue (Fig. 5.10) is the commonest form of connective tissues. It forms a thin sheet between the skin and the muscles to hold them together. It also occurs between the muscle-fibres, in the mesenteries and around the blood-vessels and nerves. It fastens the peritoneum to the body-wall and the viscera. It consists of abundant transparent, semi-fluid, sticky matrix containing numerous fibres and cells in it. The fibres are of two types : **white** and **yellow**. The white fibres are wavy and occur in bundles. They are inelastic and unbranched. They are formed of a protein called **collagen**, which on boiling with water yields a solution of gelatin. The yellow fibres are straight and occur singly. They are elastic and branched, the branches joining with one another to form a network. They are formed of a protein called the **elastin**. The cells found in the matrix are of many kinds. The common forms are the **fibroblasts**, which secrete and lie alongside the fibres; the **histocytes** or **macrophages**, which eat up the

foreign particles; and **mast cells**, which secrete the ground substance and heparin (a substance that prevents the clotting of blood).

(*ii*) **Adipose Tissue.** The adipose tissue (Fig. 5.11) is an areolar tissue in which the matrix is crowded with cells. The cells become filled with minute fat droplets. The latter finally coalesce and form larger droplets. This pushes the nucleus of cells to one side and makes the cells inflated and spherical. In prepared slides, however, the cells appear polyhedral and empty, their fat droplets having fallen out. The adipose tissue is found beneath the skin and in the fat bodies. It is mainly a food reserve, but at certain places it acts as a cushion as in the orbits or eye-sockets.

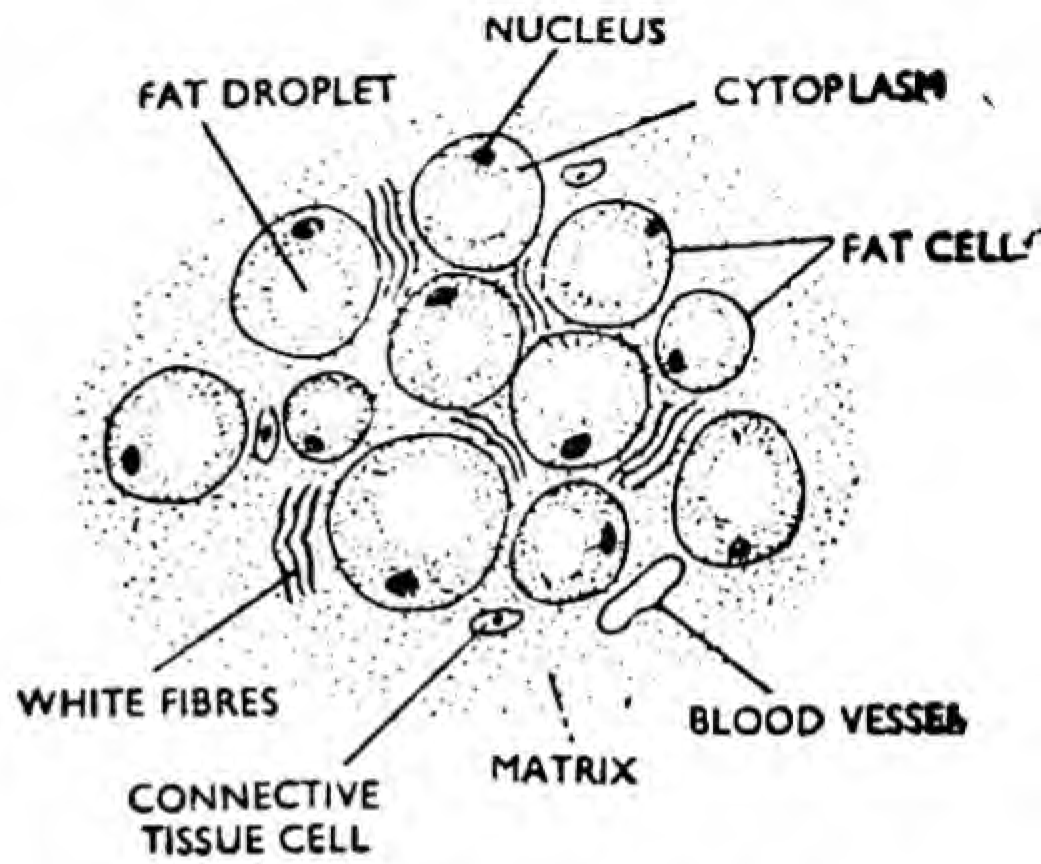


Fig. 5.11. Adipose tissue

(*iii*) **White Fibrous Tissue.** The white fibrous tissue (Fig. 5.12) consists almost entirely of closely packed white collagen fibres, which are similar to those found in the areolar tissue. The fibroblasts are elongated and lie in almost continuous rows here and there. This tissue is very tough and inelastic. The fibres may run parallel to one another to form cords or **tendons,** which connect muscles with bones or may lie criss-cross in one plane to form sheets as in the pericardium of the heart, duramater of the brain and spinal cord, sclerotic coat and cornea of the eye-ball, capsule of the kidney and the covering of cartilage and bone.

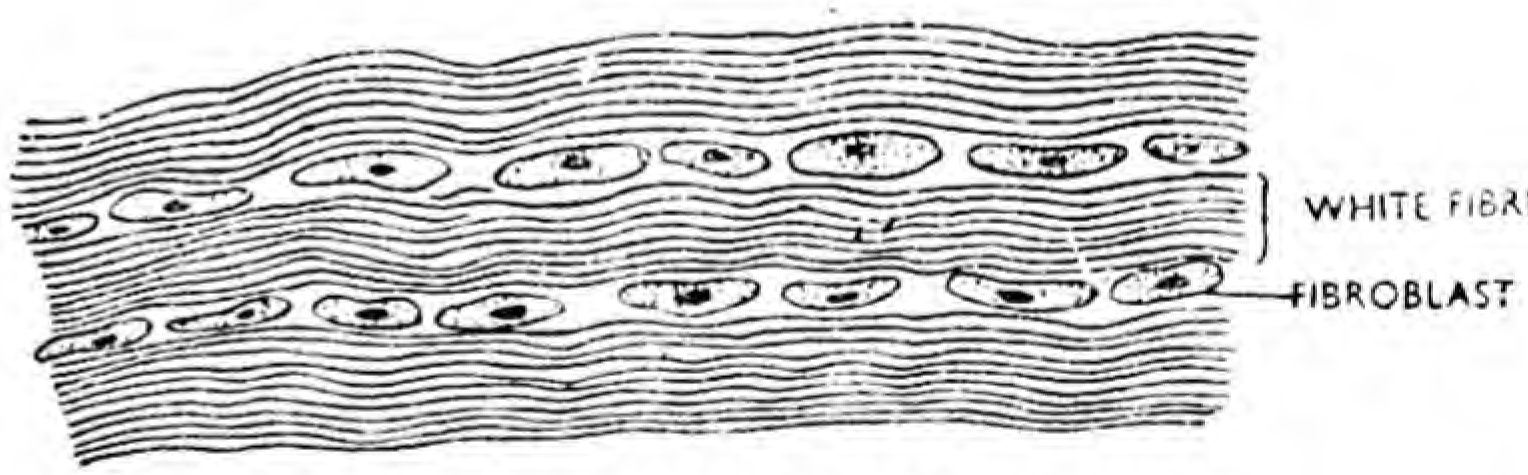


Fig. 5.12. White fibrous tissue

(*iv*) **Yellow Elastic Tissue.** The yellow elastic tissue (Fig. 5.13) consists mainly of yellow elastic fibres, which are much thicker but otherwise similar to those found in the areolar tissue. The white fibres also occur, but they are fine. The fibroblasts are scattered. This tissue combines strength with great flexibility. It may form cords or **ligaments,** which bind the bones together or sheets as in the wall of the blood-vessels and lungs.

(*v*) **Reticular Tissue.** The reticular tissue is a connective tissue in which the intercellular substance is largely replaced by lymph, white

fibres form a loose network and elastic fibres are few or none. This tissue is found in the spleen.

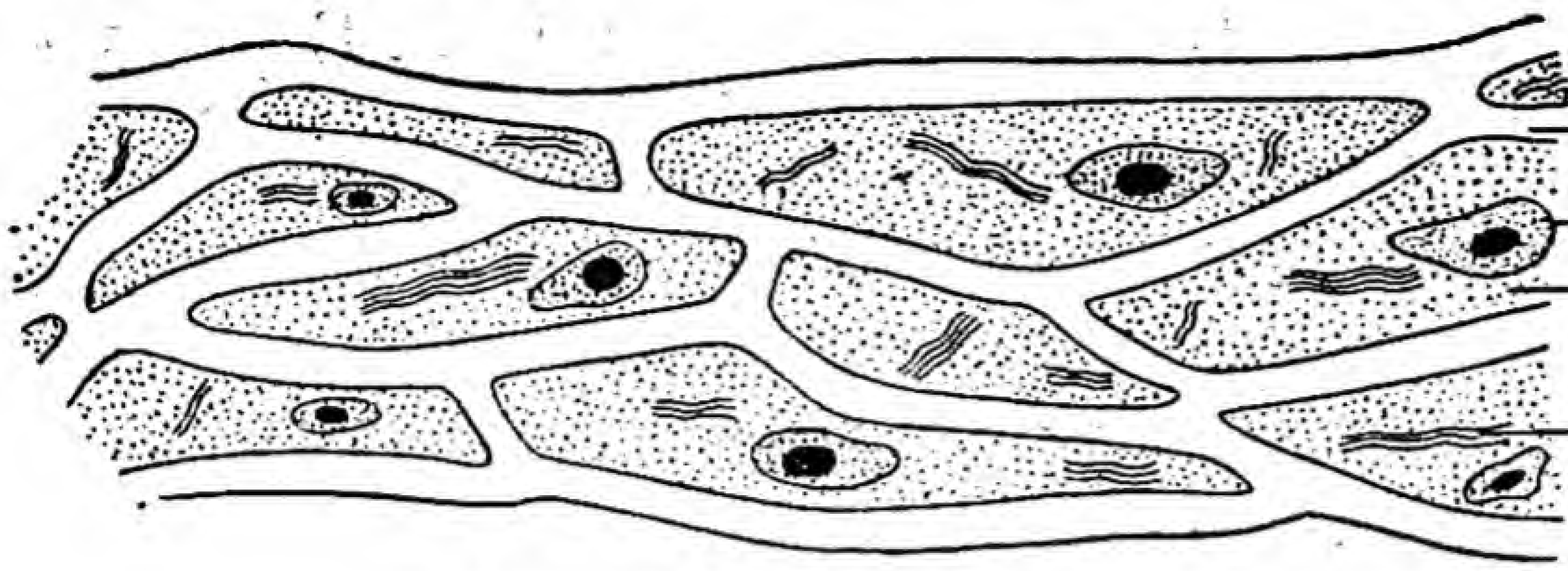


Fig. 5.13. Yellow elastic tissue

2. **Skeletal Tissues.** The skeletal tissues are characterised by the possession of a tough matrix. They form a rigid framework, which supports the body, protects the more vital organs, provides hard surface for muscle attachment and helps in locomotion. There are two types of skeletal tissues : **cartilage** and **bone.**

(*i*) **Cartilage.** The cartilage (Figs. 5.14 and 5.15) consists of a matrix of firm material, the **chondrin,** secreted by oval cartilage cells or **chondroblasts.** The cells often lie in groups of two or more. Each cell is situated in a fluid-filled space or **lacuna.** The cartilage is bounded externally by a stiff sheath, the **perichondrium,** consisting of white fibrous

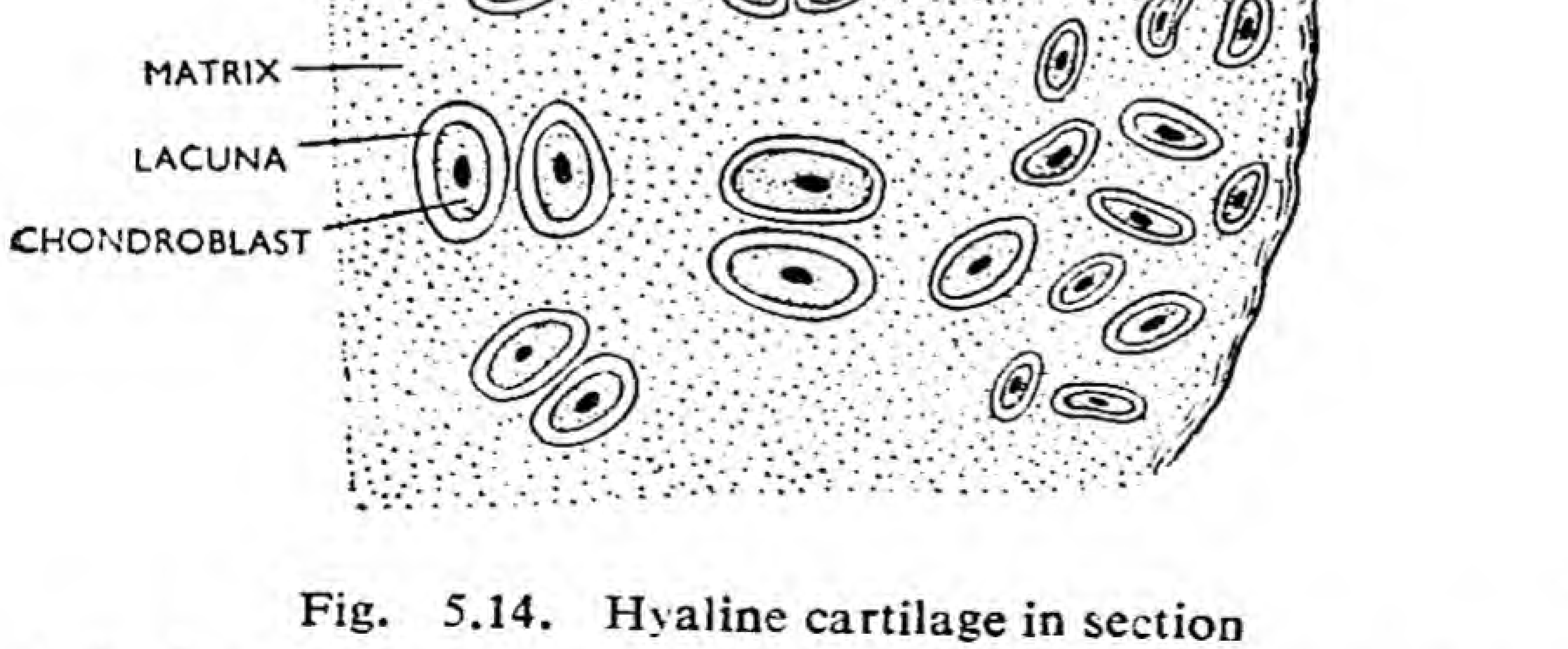


Fig. 5.14. Hyaline cartilage in section

tissue. The latter contains blood-vessels from which nutritive materials diffuse into the cartilage. Near the perichondrium, the **lacunae** are smaller and lie closer together.

The cartilage is of three types : **hyaline, fibrous** and **calcified.**

(*a*) The **Hyaline Cartilage** (Fig. 5.14) has a clear translucent and slightly elastic matrix. It often contains network of very fine collagen fibres, but they are very difficult to observe. This cartilage is found at the ends of the limb-bones and sternum, in the hyoid apparatus and in the dorsal free edge of the supra-scapula.

(*b*) The **Fibrous Cartilage** (Fig. 5.16) contains fibres in the matrix. This cartilage is further of two types : **fibro-cartilage** and **elastic cartilage.** The former has abundant white fibres, is very firm and occurs in the intervertebral discs. The elastic cartilage has numerous yellow fibres, is very flexible, readily recovers its shape if distorted and it is found in the pinna of the ear, epiglottis and eustachian tubes.

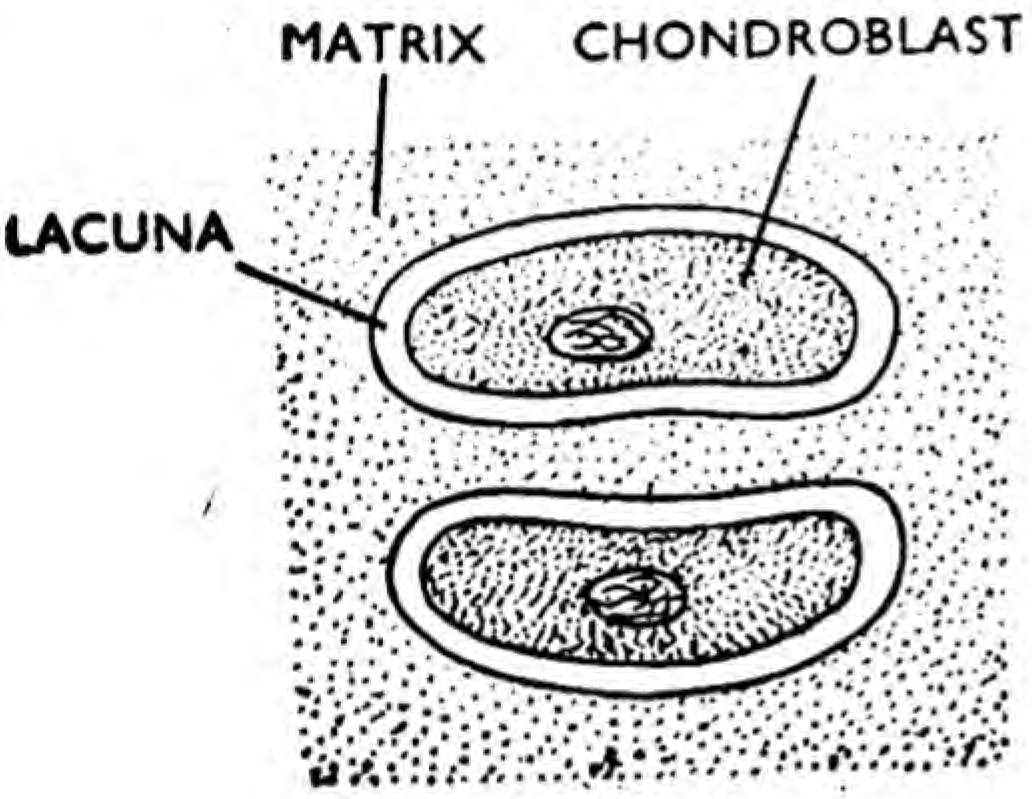


Fig. 5.15. Two cartilage cells in lacunae (Magnified)

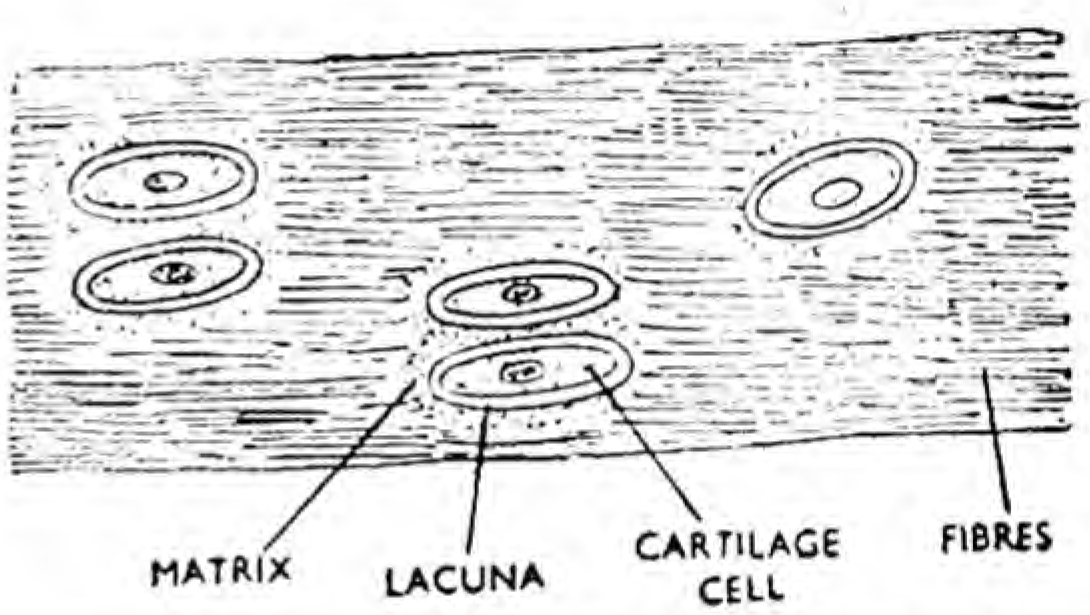


Fig. 5.16. Fibrous cartilage in section

(*c*) The **Calcified Cartilage** has calcium salts deposited in the matrix. It is very hard and inelastic. It is found in the suprascapula.

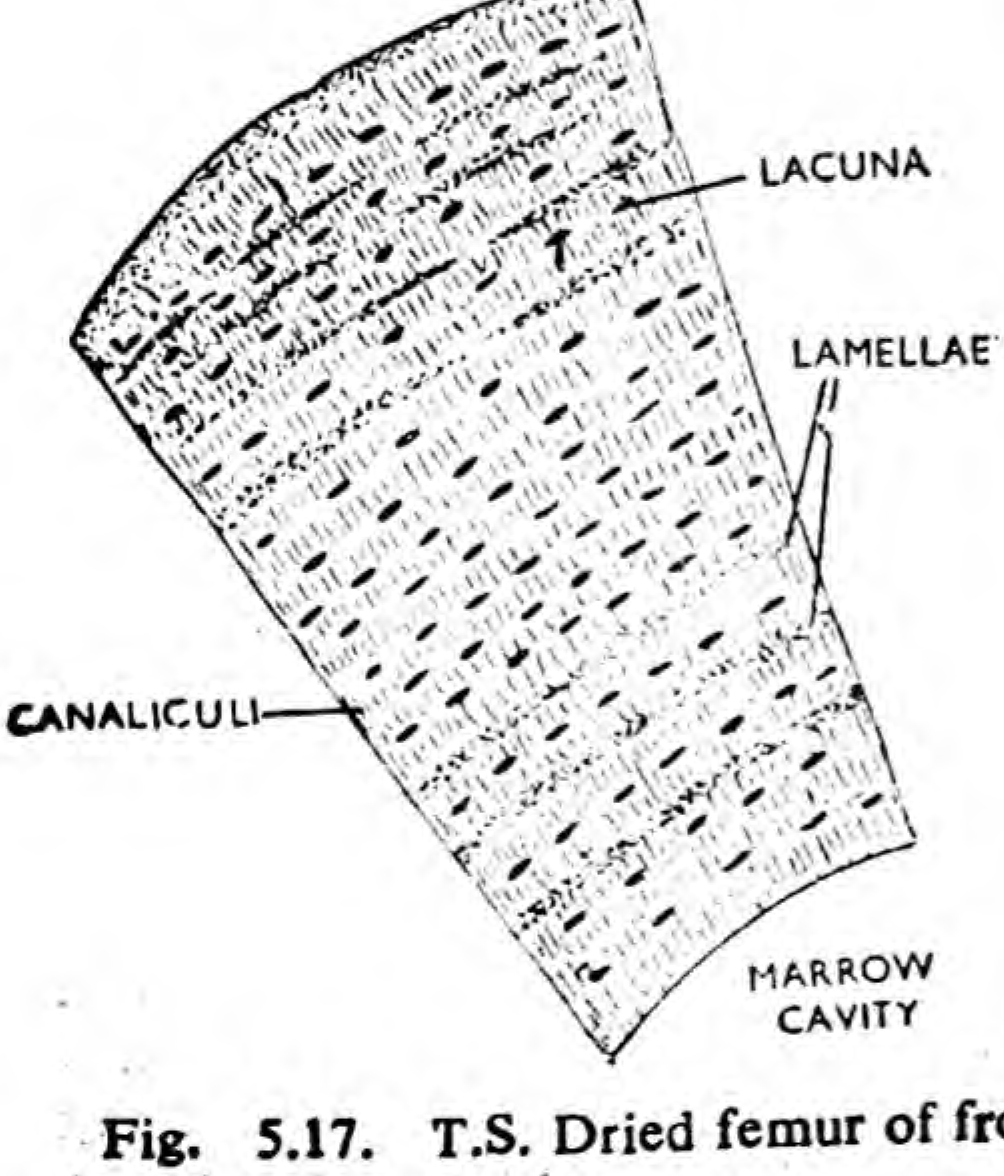


Fig. 5.17. T.S. Dried femur of frog

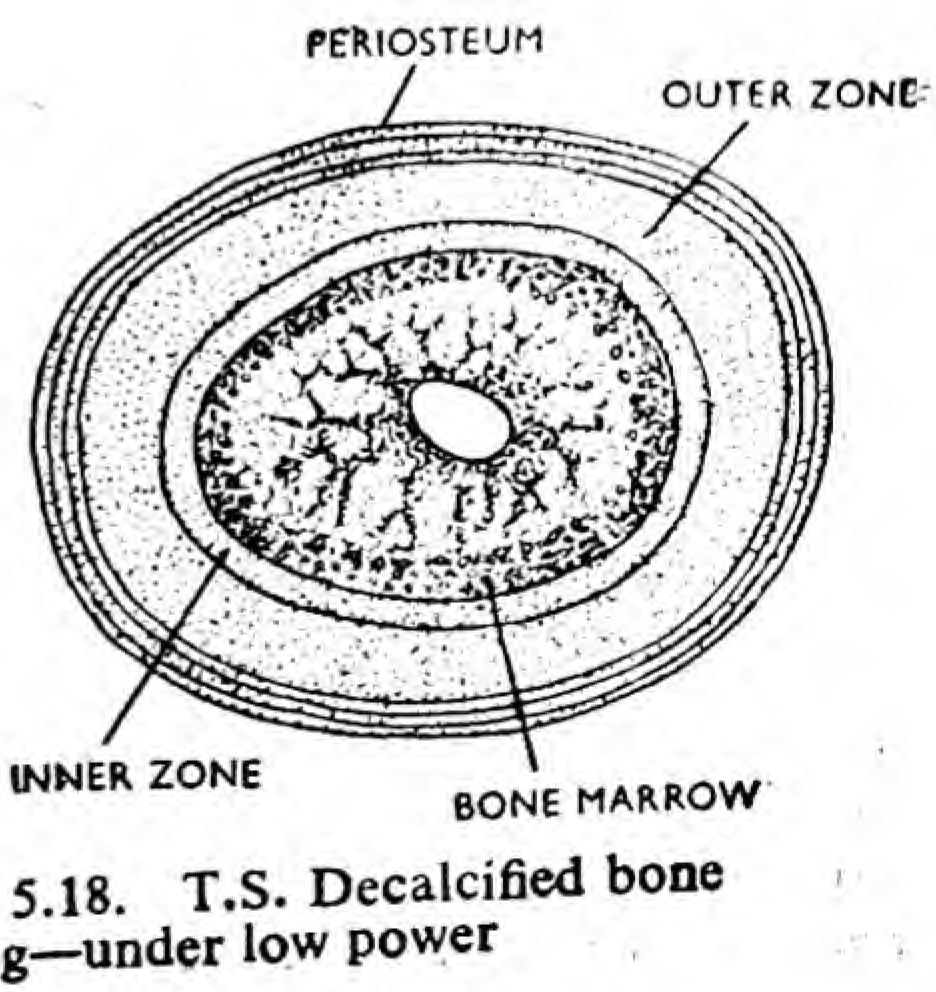


Fig. 5.18. T.S. Decalcified bone of frog—under low power

(*ii*) **Bone.** Bone is the hardest tissue in the animal body. It consists of a tough intercellular substance or **matrix** containing irregular cells or **osteocytes.** The matrix is formed of a protein called **ossein.** It contains a strengthening framework of white or collagen fibres. The fibres are, however, not visible, as they are heavily impregnated with inorganic salts, chiefly calcium phosphate and carbonate. Bone, thus, combines inorganic or mineral matter with organic or animal matter. If a bone is dried, its organic matter is destroyed and inorganic part is left behind. On the other hand, if a bone is kept in an acid for some time, its mineral part is dissolved and animal part is left behind. Such a bone is said to be decalcified. Examination of a dried bone reveals its mineral matter, while that of a decalcified bone shows the animal matter.

(*a*) **Dried Bone.** A thin section of a dried bone (Fig. 5.17) shows a large cavity, the **marrow cavity,** at its centre. This cavity is surrounded by concentric layers or **lamellae** of the matrix. The lamellae have numerous small spaces, the **lacunae.** Each lacuna gives off fine branching channels radiating in all directions. These are called the **canaliculi.** The canaliculi of adjacent lacunae join each other forming a sort of network.

(*b*) **Decalcified Bone.** A thin section of decalcified bone (Figs. 5.18 and 5.19) shows that the marrow cavity is filled with a fat-laden tissue

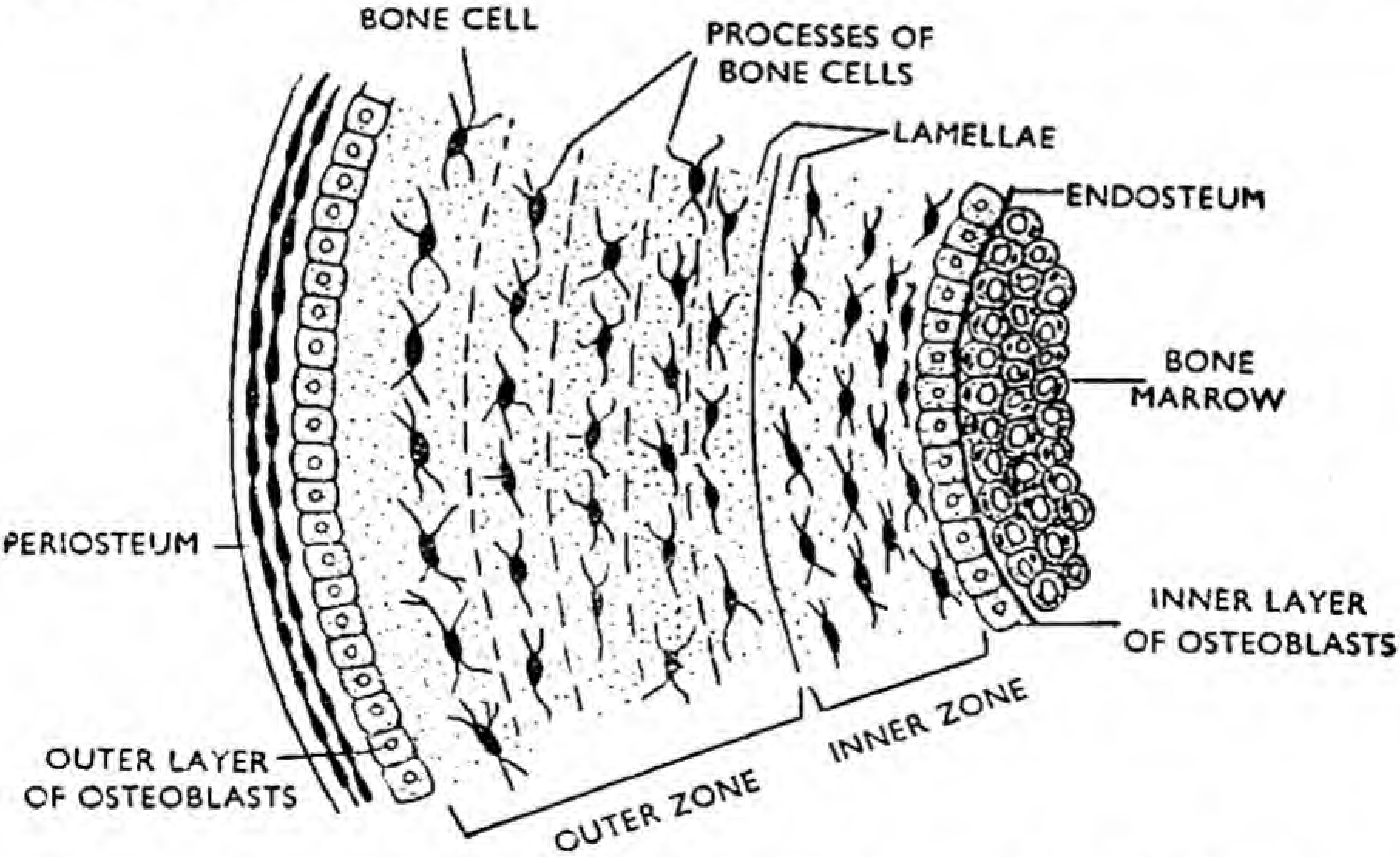


Fig. 5.19. T.S. Decalcified bone of frog—under high power

and blood-vessels collectivly forming the **bone marrow.** The bone marrow is surrounded by lamellae with bone cells in the lacunae. Each bone cell gives off protoplasmic processes, which extend into the canaliculi. The processes of the adjacent cells, like the canaliculi, unite to form a continuous network throughout the matrix (Fig. 5.20). Lacunae and canaliculi contain a fluid, which enables the bone cells to live in a medium, which is otherwise solidified by mineral salts. This fluid comes from the blood-vessels, which form an extensive inter-communicating system in the matrix. The bone is covered externally by a firm sheath

of white fibrous tissue. It is known as the **periosteum.** Beneath the periosteum and around the bone marrow lie the outer and inner layers of the bone-forming cells or **osteoblasts**. The osteoblasts produce new bone-cells. The bone, thus, grows from two sides.

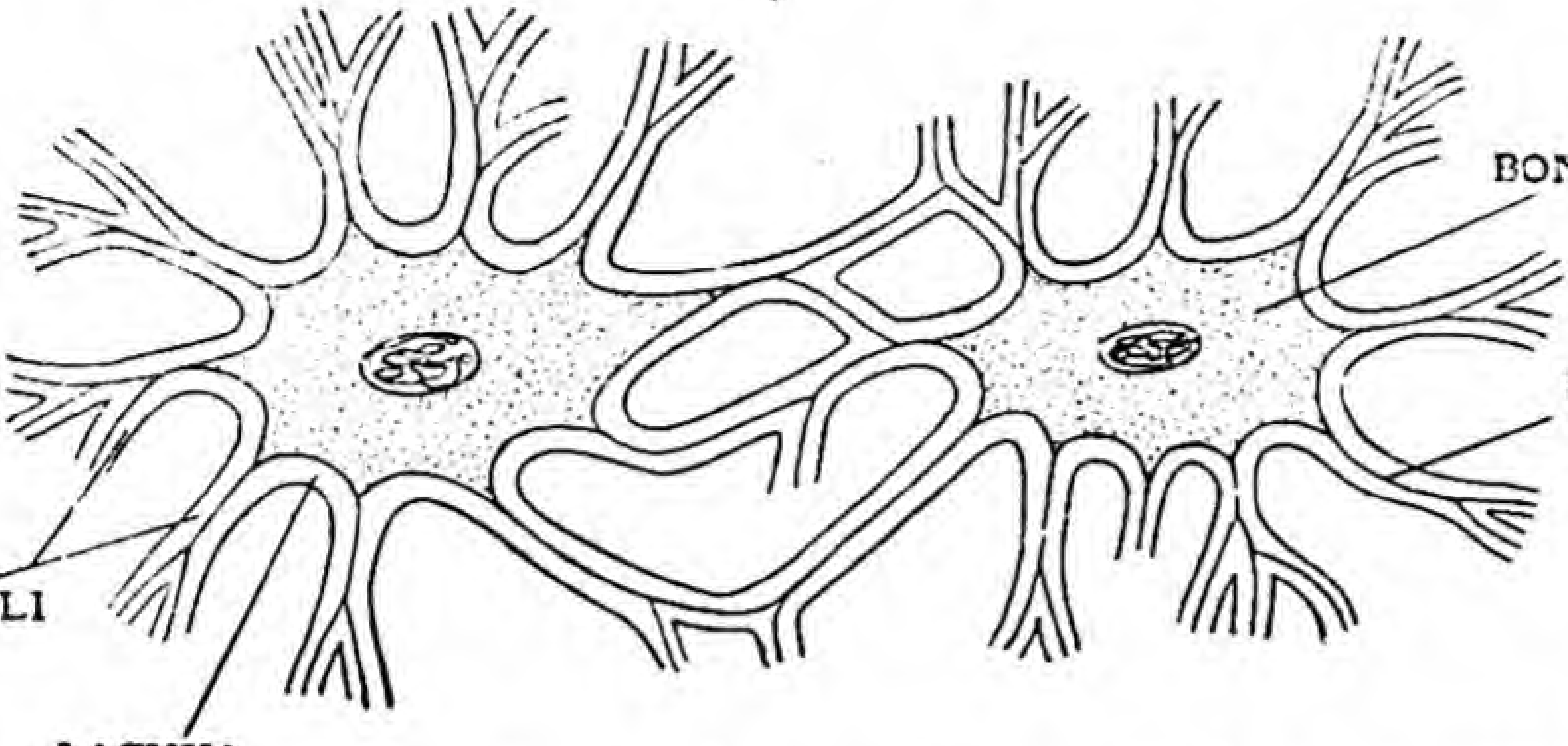


Fig. 5.20. Bone cells and their processes with lacunae and canaliculi

3. **Vascular Tissues.** The vascular tissues are characterized by the presence of a large amount of intercellular substance which is fluid in nature, circulates in the body, lacks fibres and is not secreted by the cells it contains. They are concerned with the transport of materials in the body and with its defence from the microbes. **Blood** and **lymph** are the two types of vascular tissues.

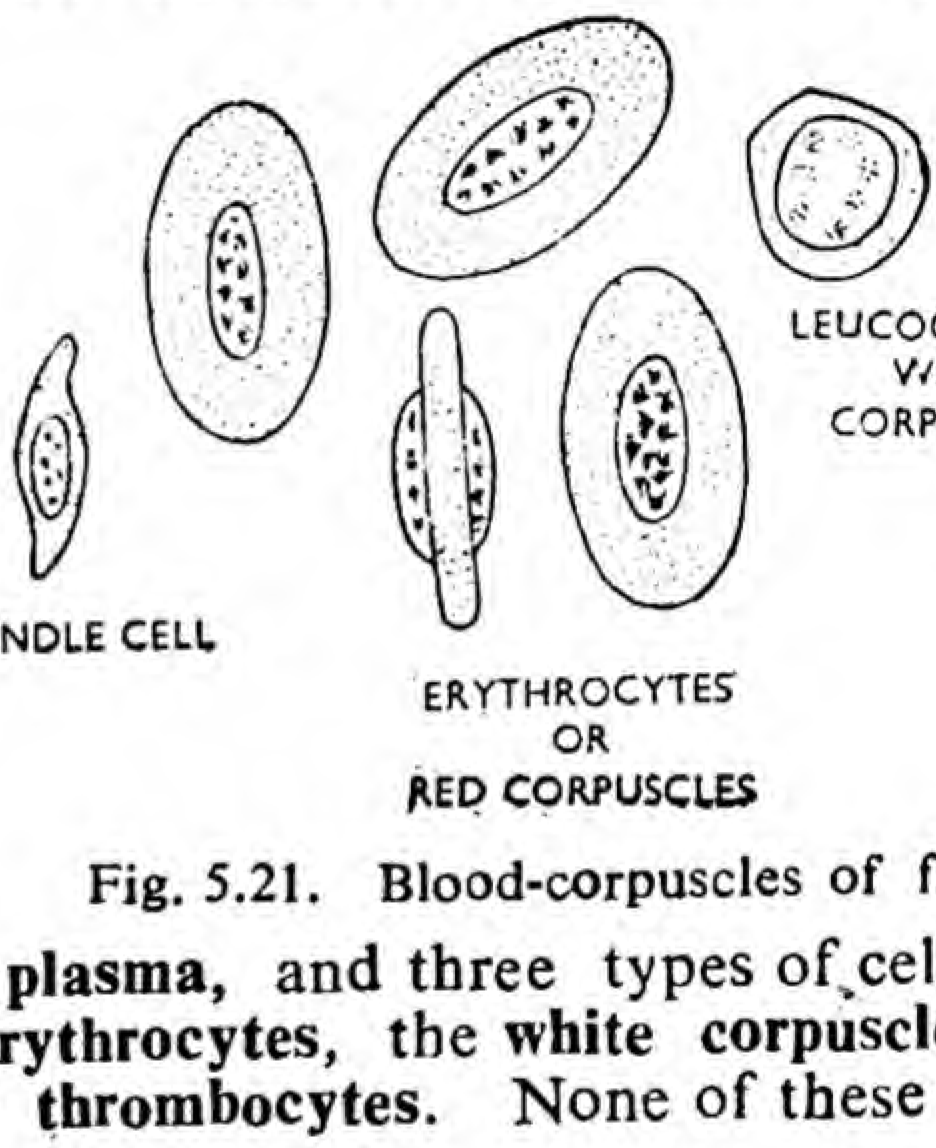


Fig. 5.21. Blood-corpuscles of frog

(*i*) **Blood**. The blood (Fig. 5.21) is a red vascular tissue. It consists of a liquid matrix, the **plasma,** and three types of cells or corpuscles : the **red corpuscles** or **erythrocytes**, the **white corpuscles** or **leucocytes** and the **spindle cells** or **thrombocytes**. None of these cells divides or multiplies in the plasma.

(*a*) **Plasma**. The plasma is a pale-yellow liquid having a number of inorganic salts in solution and a few blood-proteins in colloidal state. Many other substances like foods, wastes, gases and secretions are also invariably found in the plasma. They, however, do not form a part of the plasma as they enter and leave it at intervals. They are, in fact, on the way to their destination in the body.

(*b*) **Red Corpuscles**. The red corpuscles are nucleated, biconvex, oval discs. Individual red corpuscles are pale-yellow in colour, but they appear red in a mass. They impart red colour to the blood. This colour is due to the presence of a pigment called **haemoglobin** in them. The new red corpuscles are produced and the worn out ones are destroyed in the liver and spleen. The red corpuscles carry oxygen from **the respiratory organs to the rest of the body as oxyhaemoglobin.**

(*c*) **White Corpuscles.** The white corpuscles are nucleated, colourless and irregular cells. They are less numerous than the red corpuscles. They can change their shape and are capable of performing slow amoeboid movements. They are produced in the liver and spleen. They serve to destroy foreign germs and worn out cells.

(*d*) **Spindle Cells.** The spindle cells are small spindle-shaped bodies with large nuclei. They probably aid in the clotting of blood like the thrombocytes of mammalian blood.

(*ii*) **Lymph.** The lymph is a colourless vascular tissue. It surrounds the body-tissues. It consists of two parts : a fluid matrix or **plasma** and **white corpuscles.** Both the components escape from the blood through the thin walls of the capillaries, the plasma by ultrafiltration or diffusion under pressure and the corpuscles by amoeboid locomotion. The lymph bathes the tissues and acts as a "middle man" to hand over food and oxygen from the blood to the body-cells and waste materials from the latter to the blood. It finally returns to the blood through lymph channels and lymph vessels.

IV. Nervous Tissue

The nervous tissue forms the nervous system of the animal. It develops from the ectoderm of the embryo. It consists of nerve-cells or **neurons**, processes of nerve-cells or **nerve-fibres** and undifferentiated packing cells or **neuroglia cells.** There is no intercellular substance.

1. Nerve-cells. A nerve-cell or neuron (Fig. 5.22) consists of the **cell body** or **cyton** and processes arising from it. The cell body varies in size, shape and number of its processes. Like any other cell, it has cytoplasm, here called **neuroplasm,** and nucleus. The nucleus contains a prominent nucleolus. The cytoplasm has numerous fine threads, the **neurofibrils**, and small granules, the **Nissl granules**. Usually, a neuron has two types of processes : a very long cylindrical **axon** and short tapering **dendrites.** Both types of processes end in a cluster of branches, the **terminal arborization.** The neurofibrils extend into both types of processes, but Nissl granules occur only in the dendrites.

The neurons function in co-operating chains, each receiving the impulse and passing it on to another till an effect is produced in some part of the body. They receive the impulse through the dendrites and transmit it through the axon. For cell-to-cell relay of impulse, the terminal arborizations of axon and dendrites come close together, leaving only a microscopic gap. This close juxtaposition of the axon of one cell and the dendrites of another without actual contact is known as **synapse**. An impulse does not travel across the synapse. A chemical called acetylcholine is released by the terminal arborization of the axon and this sets up a fresh impulse in the dendrons of the next neuron.

A neuron with many processes is said to be **multipolar.** Such neurons occur in the brain and spinal cord. A neuron may have only two processes, an axon at one end and a dendrite at another (Fig. 5.23). Such neurons are described as **bipolar.** They are found in the retina of

the eye. There may be a single process arising from the neuron. Such neurons are termed **unipolar**.

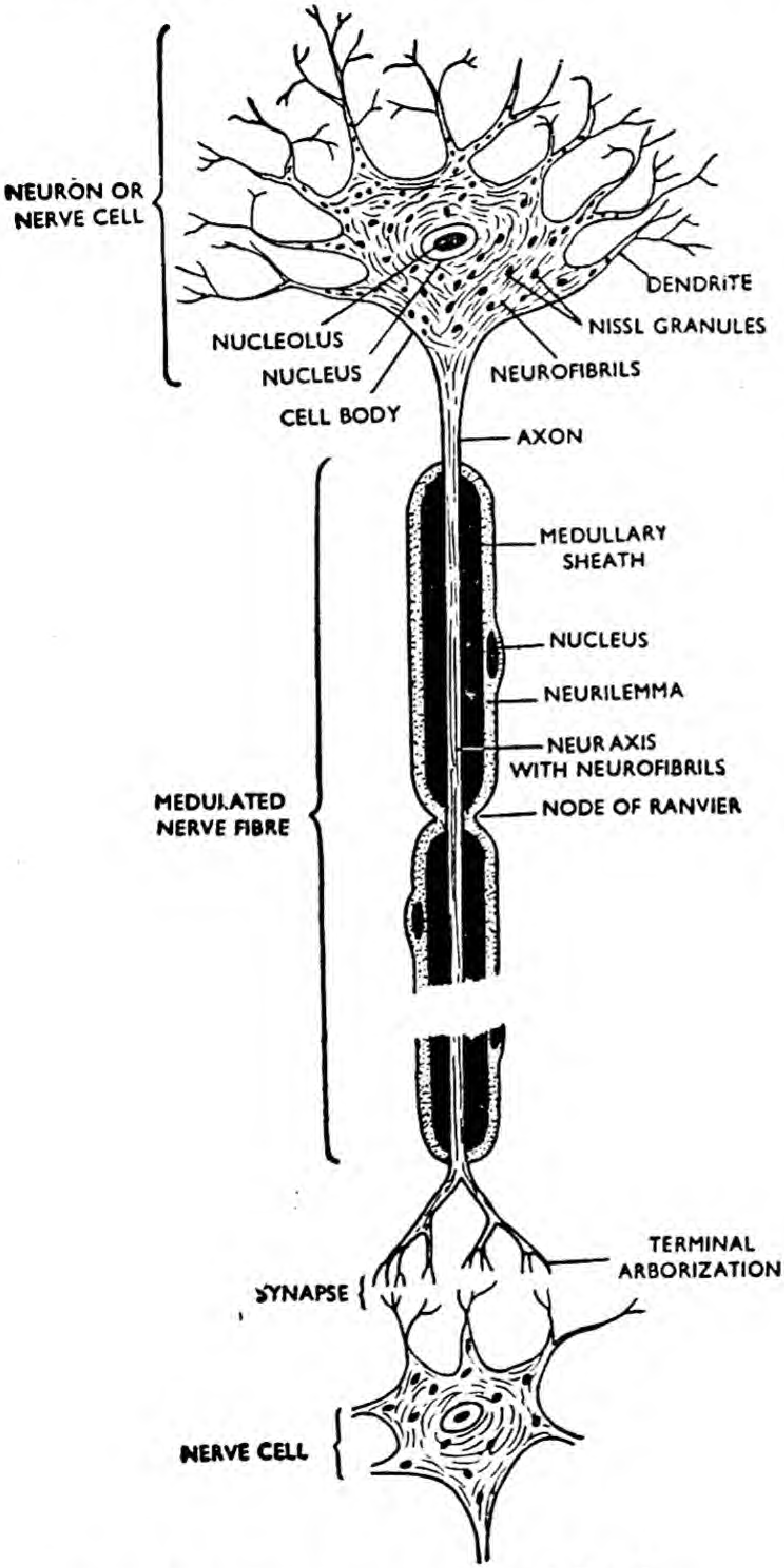


Fig. 5.22. Two nerve-cells, a medullated **nerve-fibre** and synapse

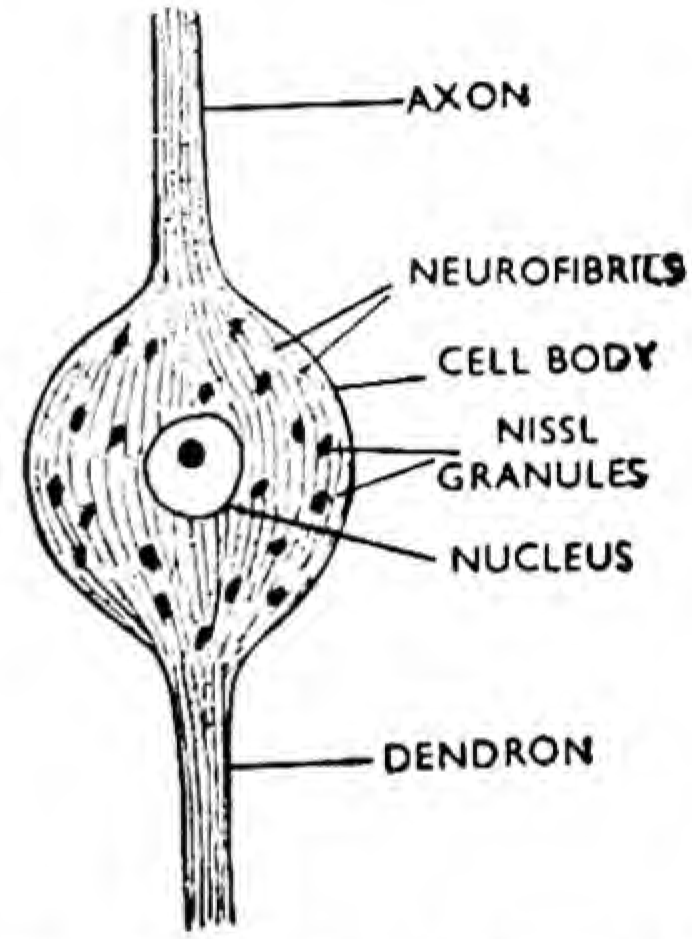


Fig. 5.23. A bipolar neuron

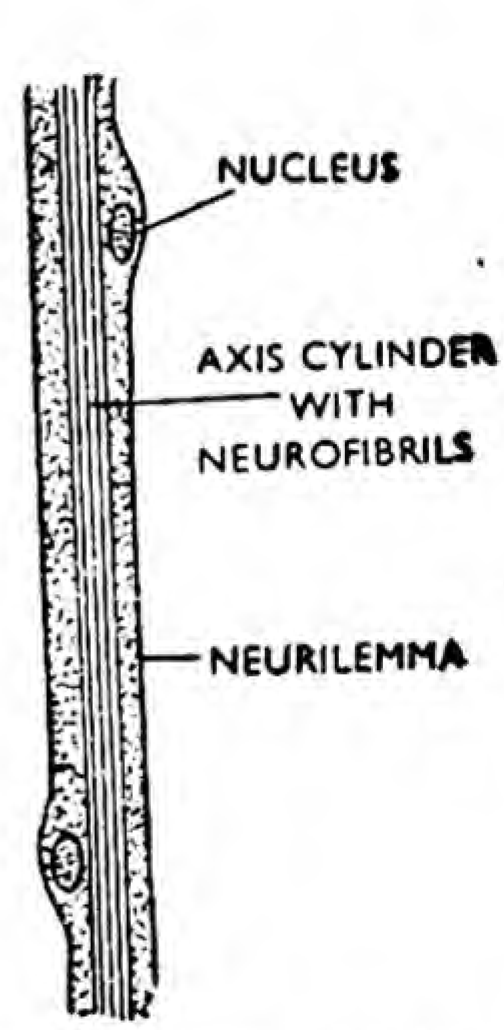


Fig. 5.24. A non-medullated nerve-fibre

The various types of tissues discussed above are summarised below :

- Tissues
  - Epithelial Tissues
    - Simple Epithelia
      1. Squamous
      2. Cuboida
      3. Columnar
         - (a) Glandular
         - (b) Sensory
      4. Ciliated
      5. Germinal
    - Compound Epithelia
      1. Stratified
      2. Transitional
  - Muscular Tissues
    1. Visceral or Smooth
    2. Skeletal or striated
    3. Cardiac
  - Connective Tissues
    - Connective Tissues Proper
      1. Areolar
      2. Adipose
      3. White Fibrous
      4. Yellow Elastic
      5. Reticular
    - Skeletal Tissues
      1. Cartilage
         - (a) Hyaline
           - Fibrocartilage
           - Elastic cartilage
         - (b) Fibrous
         - (c) Calcified
      2. Bone
    - Vascular Tissues
      1. Blood
      2. Lymph
  - Nervous Tisseus
    - Neurons
      1. Unipolar
      2. Bipolar
      3. Multipolar
    - Nerve Fibres
      1. Medullated
      2. Non-medullated
    - Neuroglia cells

2. **Nerve-fibres**. An axon covered with one or two sheaths is termed a **nerve-fibre**. Nerve-fibres are of two types : **medullated** or **myelinated** and **non-medullated** or **unmyelinated**.

The **medullated nerve-fibres** (Fig. 5.22) occur in the white matter of the brain and spinal cord and in the cranial and spinal nerves. Each fibre consists of a central core, the **axis cylinder** or **neuraxis**, surrounded by two sheaths, the inner thick **medullary** or **myelin sheath** and the outer thin **neurilemma**. The axis cylinder is a cytoplasmic continuation of the axon of the nerve-cell and contains neurofibrils. The medullary sheath is a glistening-white fatty layer. It is continuous in the central nervous system, but in the nerves it is absent at certain points known as the **nodes of Ranvier**. The part of the nerve-fibre between two successive nodes is termed the **internode**. The neurilemma consists of the tubular **sheath cells**, a single cell with a single large nucleus covering an internode. The neurilemma is continuous over the nodes of Ranvier, where the cytoplasm of the sheath cells is constricted and touches the axis cylinder. Outside the neurilemma is a fine layer of connective tissue.

The **non-medullated nerve-fibres** (Fig. 5.24) are found in the sympathetic nervous system. They lack a medullary sheath and appear grey in colour. Each fibre consists of an axis cylinder, neurilemma and a layer of connective tissue.

Nerve-fibres conduct impulses in one direction only, *i.e.* either from the sense-organs to the central nervous system or from the central nervous system to the muscles and glands. They are respectively called the **afferent** or **sensory fibres** and **efferent fibres**.*

A nerve consists of bundles of nerve-fibres. The nerve fibres in a bundle are bound together by coats of white fibrous tissue called **perineurium**. The bundles are held together by another fibrous coat termed the **epineurium**. A nerve may have afferent fibres only (afferent nerve), efferent fibres only (efferent nerve)* or both types of fibres (mixed nerve).

ORGANS

Tissues combine and coordinate their activities for a common purpose. Such a combination of tissues is termed an **organ**. The histology of the chief organs of frog is described below.

Skin. The skin consists of two regions : the outer thin non-vascular **epidermis** and the inner thick vascular **dermis** (Fig. 5.25).

1. **Epidermis**. The epidermis develops from the ectoderm of the embryo. It is a stratified epithelium, as it is formed of several layers of cells. The innermost layer consists of columnar cells and is known as the Malpighian layer or **stratum germinativum**. The cells of this layer divide by mitosis to produce new cells. The new cells pass outwards and in this process they gradually become flat and their cytoplasm is

*Efferent fibres and efferent nerves are sometimes wrongly called "motor". They are motor only if they innervate the striped muscles, which are responsible for locomotion. They are secretory when supplied to the glands and so on.

slowly replaced by a hard substance, the **keratin** or **horn**. By the time they reach the surface of the epidermis, they become extremely thin and completely dead. They are said to constitute the **horny layer** or **stratum corneum**. This layer is protective in function. It is cast off periodically in shreds or as thin sheets. These are called castings of the frog and the process is called **moulting**.

2. Dermis. The dermis develops from the mesoderm of the embryo. It consists of connective tissue in which bands of white collagen fibres predominate. The bands are mostly horizontal, *i.e.* they lie parallel to the surface of the skin. Some are vertical, *i.e.* they lie perpendicular to the surface of the skin. The white fibres provide firmness to the skin. Dermis also contains blood-capillaries, nerves and pigment cells or **chromatophores**. The blood-capillaries bring nourishment to the skin. The nerves make it sensitive to external stimuli. Fine branches of the nerves extend into the epidermis also. The pigment cells impart colour to the skin. These cells lie mostly in the outer part of the dermis. They are irregular bodies with pigment in their cytoplasm.

Flask-shaped cavities lined with glandular cells occur in the outer part of the dermis. These are called the **cutaneous glands.** Each gland has a narrow duct which passes outwards through the epidermis and opens out by a small pore on the surface of the skin. The cutaneous glands, though present in the dermis, are epidermal in origin. They

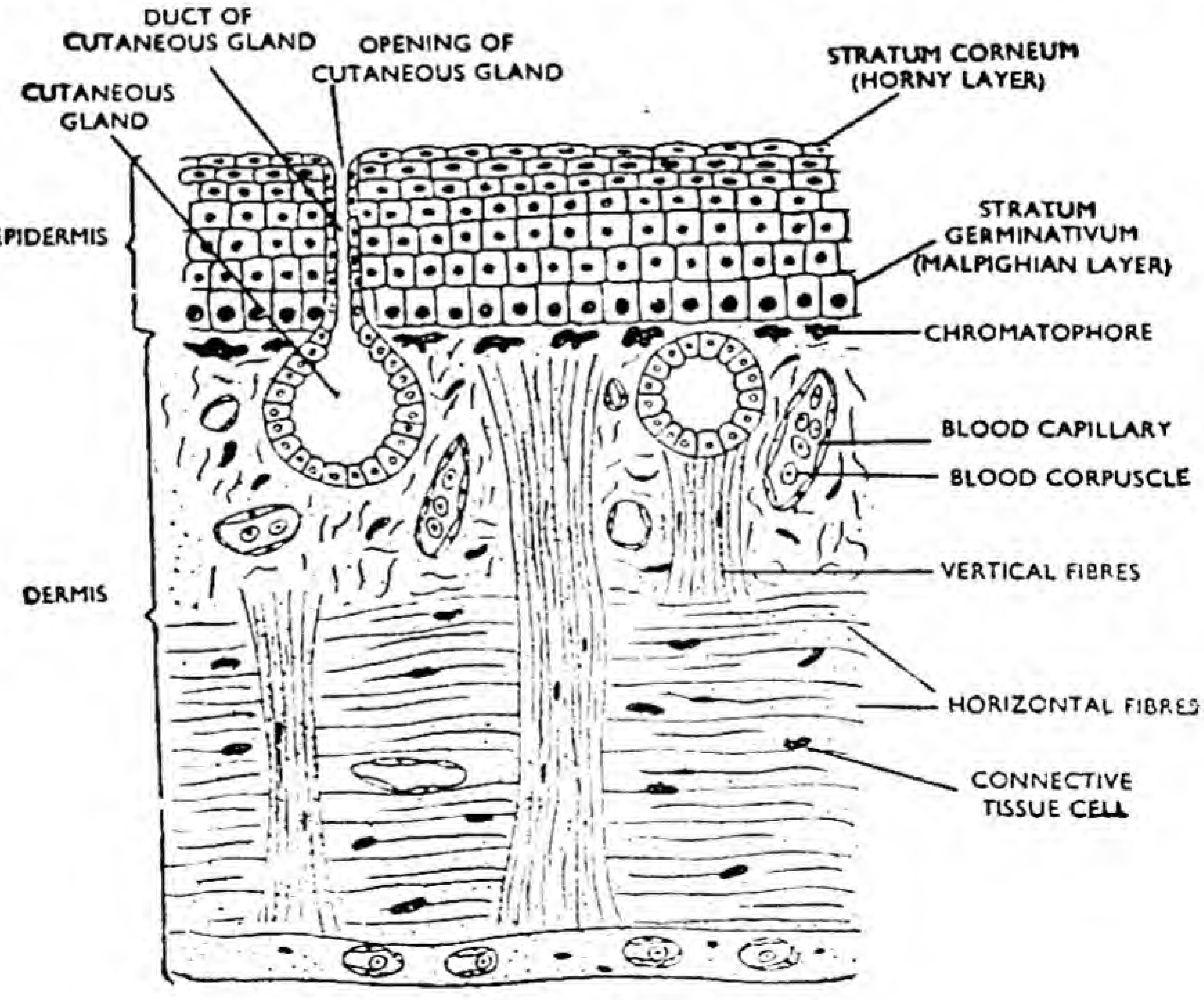


Fig. 5.25. V.S. Skin of frog

are formd by sinking in of the Malpighian layer. They secrete a slimy mucus, which spreads over the skin as a thin film. The mucus keeps the skin moist for cutaneous respiration. It also makes the frog

slippery, which facilitates its escape from the enemy's grip. Its evaporation cools the body when the animal is on land. This is why a frog in the air is always at a slightly lower temperature than its surroundings.

Intestine. The wall of the intestine is composed of four concentric coats, namely, **mucosa, submucosa, muscular coat** and **visceral peritoneum** or **serous layer.** (Figs. 5.26 and 5.27).

1. **Mucosa.** The mucosa forms the innermost coat of the intestinal wall. It further consists of three layers which, from within outwards, are known as the **columnar epithelium**, the **lamina propria** and the **muscularis mucosae**. The columnar epithelium consists of a single layer of tall cells supported on a thin basement membrane. Here and there amongst the epithelial cells occur special mucus-secreting cells, termed the **goblet cells.** Each goblet cell has near its free end a small flask-like cavity in which collects the mucus secreted by the cell itself. These cavities burst from time to time and release the mucus. The latter spreads over the inner surface of the intestine as a thin film. Due to the presence of mucus-secreting cells in it, mucosa is also known as the **mucous membrane**. The lamina propria consists of a thin sheet of reticular

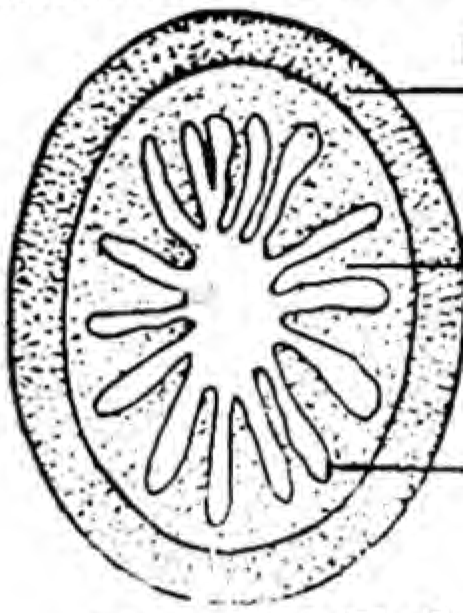


Fig. 5.26. T. S. Intestine (Ileum)

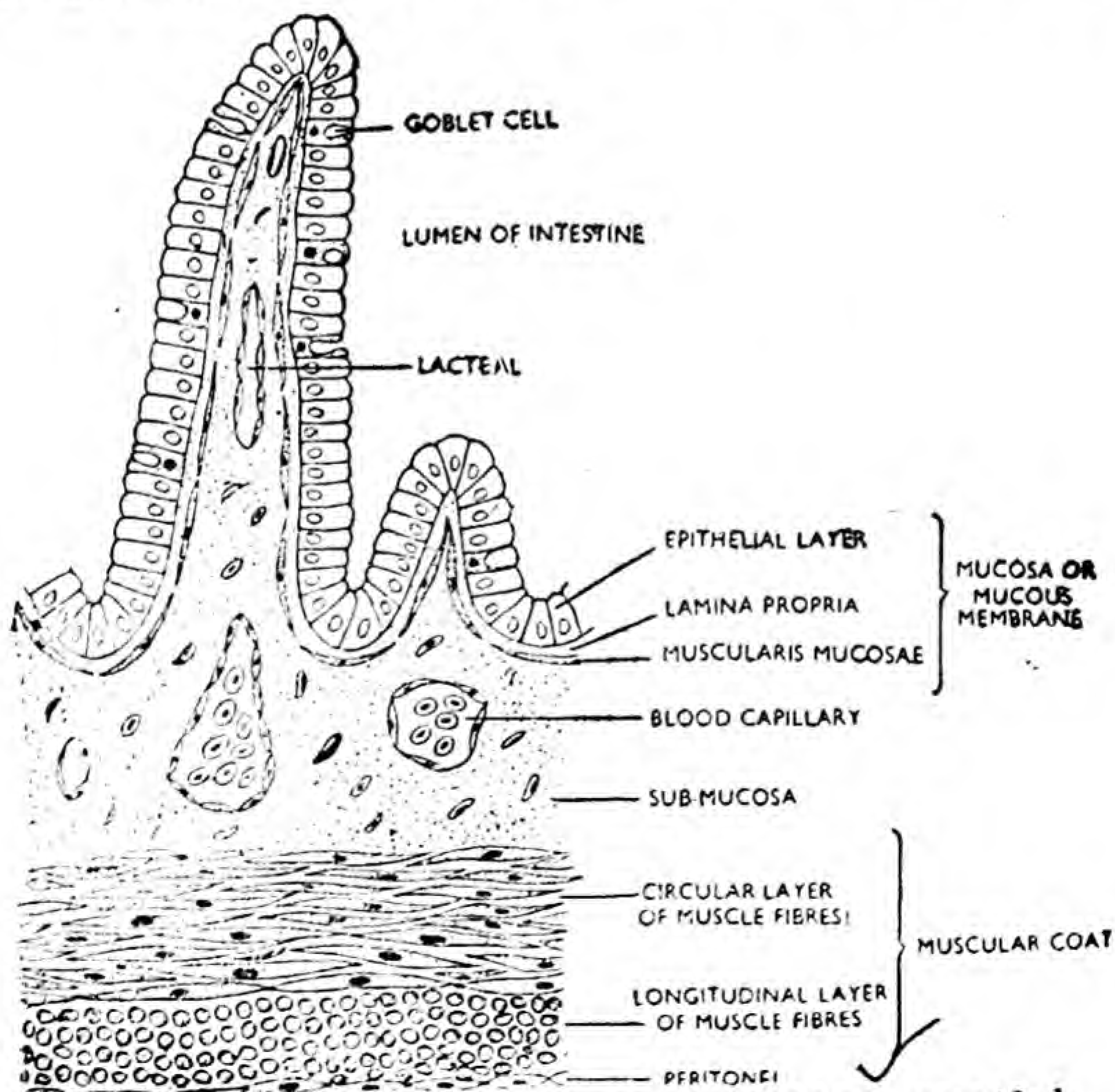


Fig. 5.27. A part of T. S. of intestine—highly magnified

connective tissue. It contains fine capillaries, lymph-vessels and nerves. The muscularis mucosae is a very thin band of unstriated muscle-fibres. The mucosa is concerned with secretion and absorption.

2. **Submucosa.** The submucosa is outside the mucosa. It consists of dense connective tissue with both white and yellow fibres. It contains larger blood-vessels and lymph-vessels (lacteals), which send branches to the mucosa on the inner side and the muscular coat on the outside. A plexus of nerve cells and fibres, called the **submucous plexus of Meissner** is also present in the submucosa. Besides carrying the circulatory fluids, blood and lymph, for the absorption of food, the submucosa also provides the elasticity essential for the expansion of the intestinal lumen.

The submucosa and the mucosa are thrown into folds to increase the inner absorptive surface of the intestine. The folds are longitudinal in the ileum and transverse in the duodenum.

3. **Muscular Coat.** The muscular coat surrounds the submucosa. **It is** formed of unstriped or smooth muscle-fibres. It is differentiated into two layers : an inner thick layer of **circular muscle-fibres,** which encircle the intestine and an outer thin layer of **longitudinal muscle fibres,**

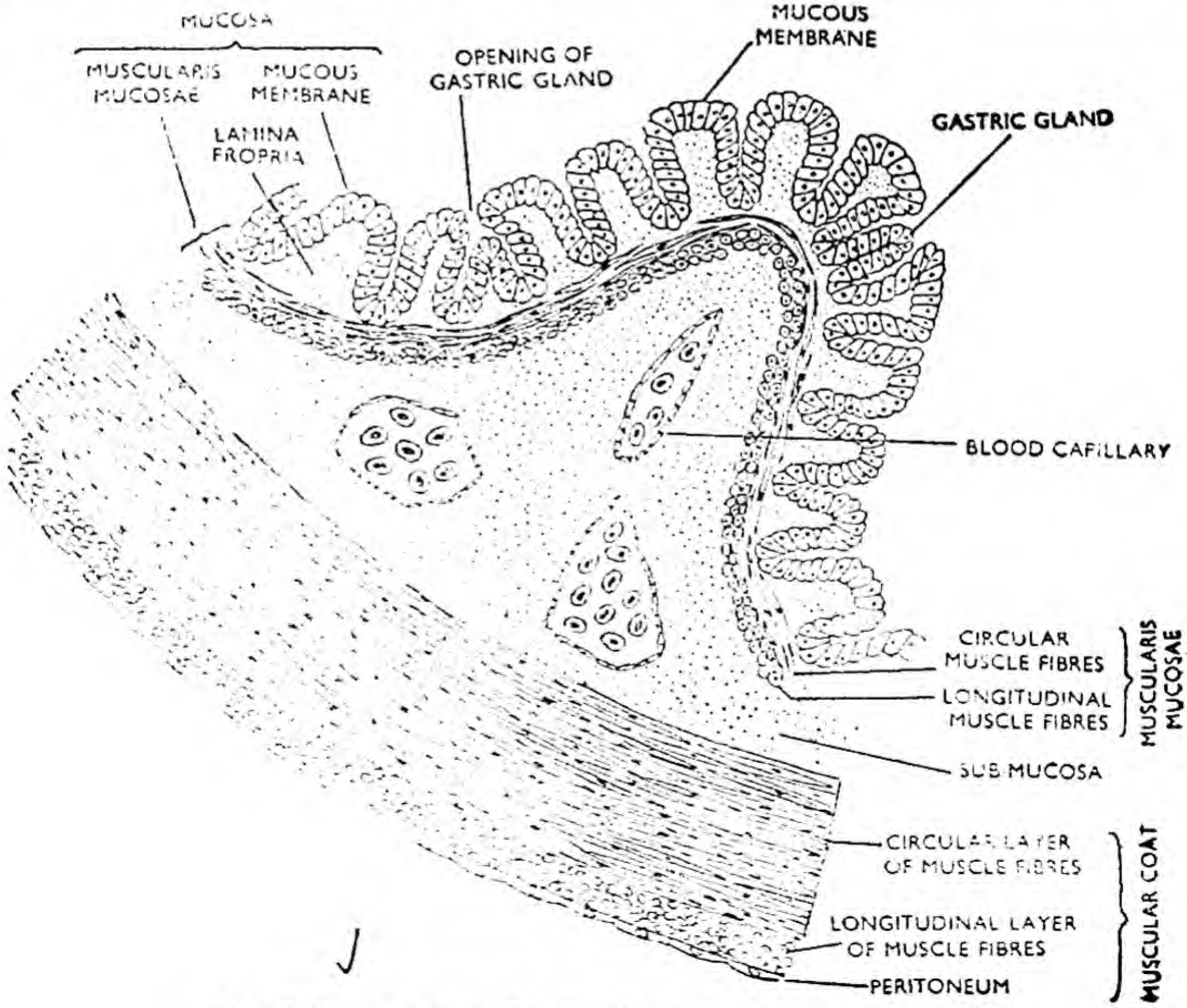


Fig. 5.28. A part of T.S. of stomach—highly magnified

which run parallel to the length of the intestine. In a transverse section of the intestine, the circular muscles appear as spindle-like fibres as they are cut length-wise, while the longitudinal muscle-fibres look like dots since they are cut across. Between the two muscular layers lies a net work of nerve-cells and fibres. This is known as the **sympathetic myenteric plexus** or **plexus of Auerbach**. The muscular layers are under the involuntary control of the autonomic nervous system of which the plexsus of Auerbach and Meissner are parts. Contractions of the muscular coat mix the food contents with the digestive juices and push them along towards the rectum.

4. Visceral Peritoneum. The peritoneum forms the outermost coat of the intestinal wall. It comprises two layers : an inner, very thin layer of connective tissue and an outer layer of flattened cells or squamous epithelium. The peritoneum serves as a protective covering. It is continuous with the mesentery, which suspends it from the body-wall.

Stomach. The wall of the stomach is composed of the same four coats, which occur in the intestinal wall. These are, from within outwards, **mucosa, submucosa, muscular coat** and **visceral peritoneum** (Fig. 5.28). The submucosa and mucosa are likewise thrown into longitudinal folds. A few differences, however, occur between the stomach and the intestine. The various coats in the stomach wall are thicker than their counterparts in the intestinal wall. This is specially noticeable in the muosa and the muscular coat. The mucosa, as in the intestine, consists of three layers : epithelial layer, connective tissue layer or lamina propria and muscular layer or muscularis mucosae. The epithelial layer, instead of forming an even layer, is invaginated into the underlying connective tissue layer in the form of simple or branched tubes.

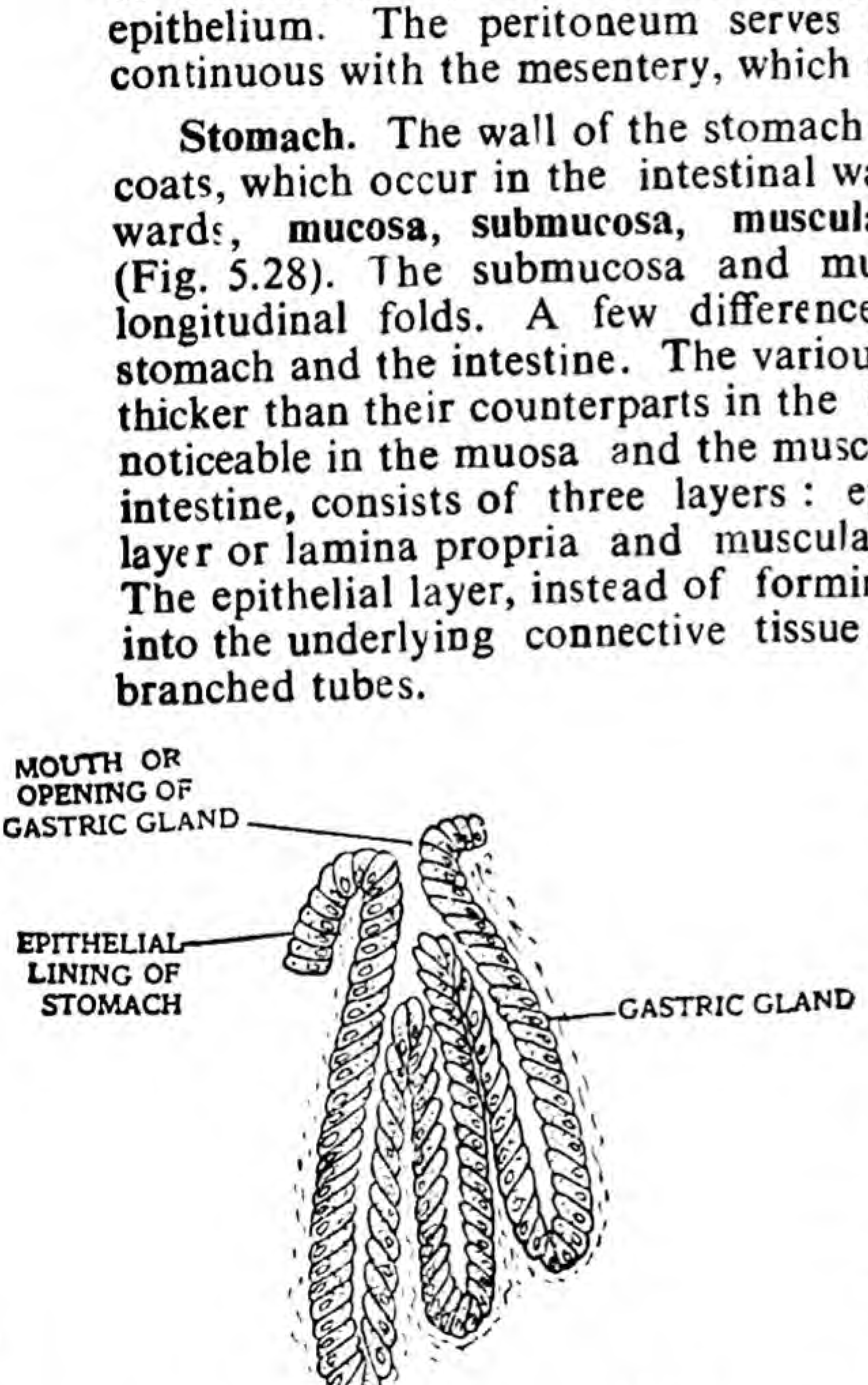


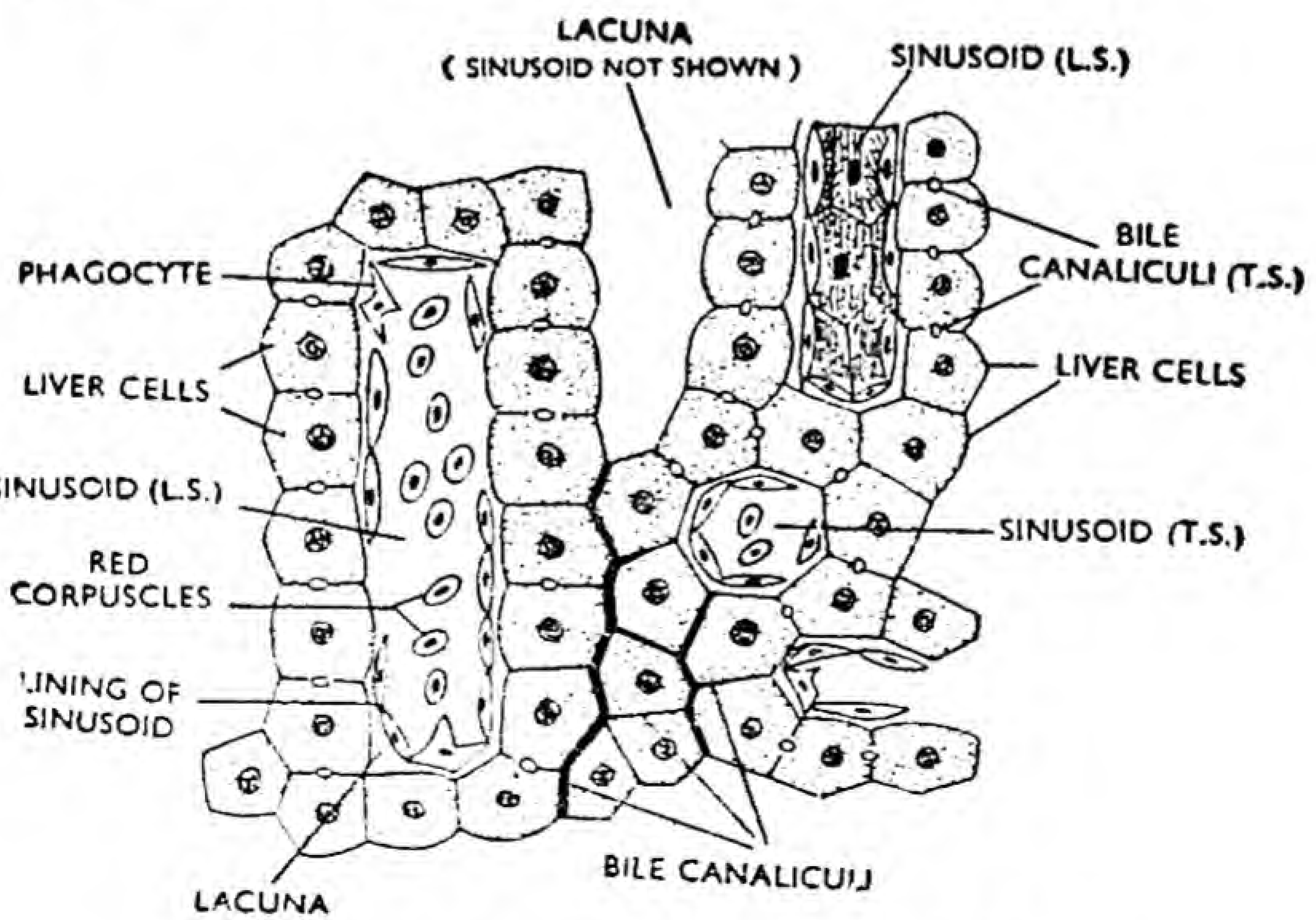
Fig. 5.29. L.S. Gastric gland

These tubes are known as the **gastric glands.** They have very narrow cavities, which are lined by glandular cells and open by minute apertures into the lumen of the stomach (Fig. 5.29). The gland cells of the gastric glands are of two types : cubical **chief** or **peptic cells** that secrete an enzyme called **pepsin** and ovoid **oxyntic cells** that secrete **hydrochloric acid.** The mixture of pepsin and hydrochloric acid forms the gastric juice. The latter passes into the cavity of the stomach through the apertures of the gastric glands. The muscularis mucosa is better developed in the stomach and consists of an inner layer of circular and an outer layer of longitudinal muscle-fibres. The muscular coat is also better

developed. It has circular fibres inside and longitudinal fibres outside. The greater development of the muscular coat enables the stomach to hold a large quantity of food and to churn it effectively. The peritoneum invests the muscular coat. It is continuous with the mesentery.

Oesophagus. The oesophageal wall is also composed of the same four coats that exist in the intestinal wall. There, however, occur a few important differences. It lacks visceral peritoneum as it does not lie in the coelom. Its mucous membrane consists of stratified squamous epithelium. Its muscle fibres are of striated or voluntary type in the beginning but gradually change to smooth or involuntary type posteriorly.

Liver. The liver (Fig. 5.30) is composed of polygonal cells, each with a prominent nucleus, glycogen granules and fat droplets. The cells are arranged in a single layer around a network of spaces or **lacunae.** The lacunae contain blood capillaries whose wall is formed of a discontinuous squamous epithelium. These capillaries are called the **sinusoids.** Here and there the epithelium of the sinusoids has irregular phagocytic cells, which ingest worn out red corpuscles. The blood from the hapatic portal vein and the hepatic artery passes through the sinusoids, which ultimately empty into the hepatic vein. The liver is, thus, a spongy organ in the course of the blood from the gut to the heart. In ihe sinusoids the blood comes very close to the liver-cells, which regulate the amount of food materials in the blood. The liver-cells also secrete bile. It is poured into fine **canaliculi**, which are simply intercellular channels between the adjacent liver-cells, having no lining of their own. The canaliculi join to form **bile-ductules**, which in turn unite to form the main bile-ducts.



5.30. A part of a section of liver of frog

Pancreas. The pancreas (Fig. 5.31) is composed of a large number of minute rounded masses, the **lobules** or **acini,** arranged like grapes

in a bunch. The lobules are held together by connective tissue. The latter contains blood-capillaries, lymph-channels and nerves. Each lobule or acinus has a narrow cavity or lumen, which is enclosed by a single layer of columnar cells. The cells are glandular in nature, have

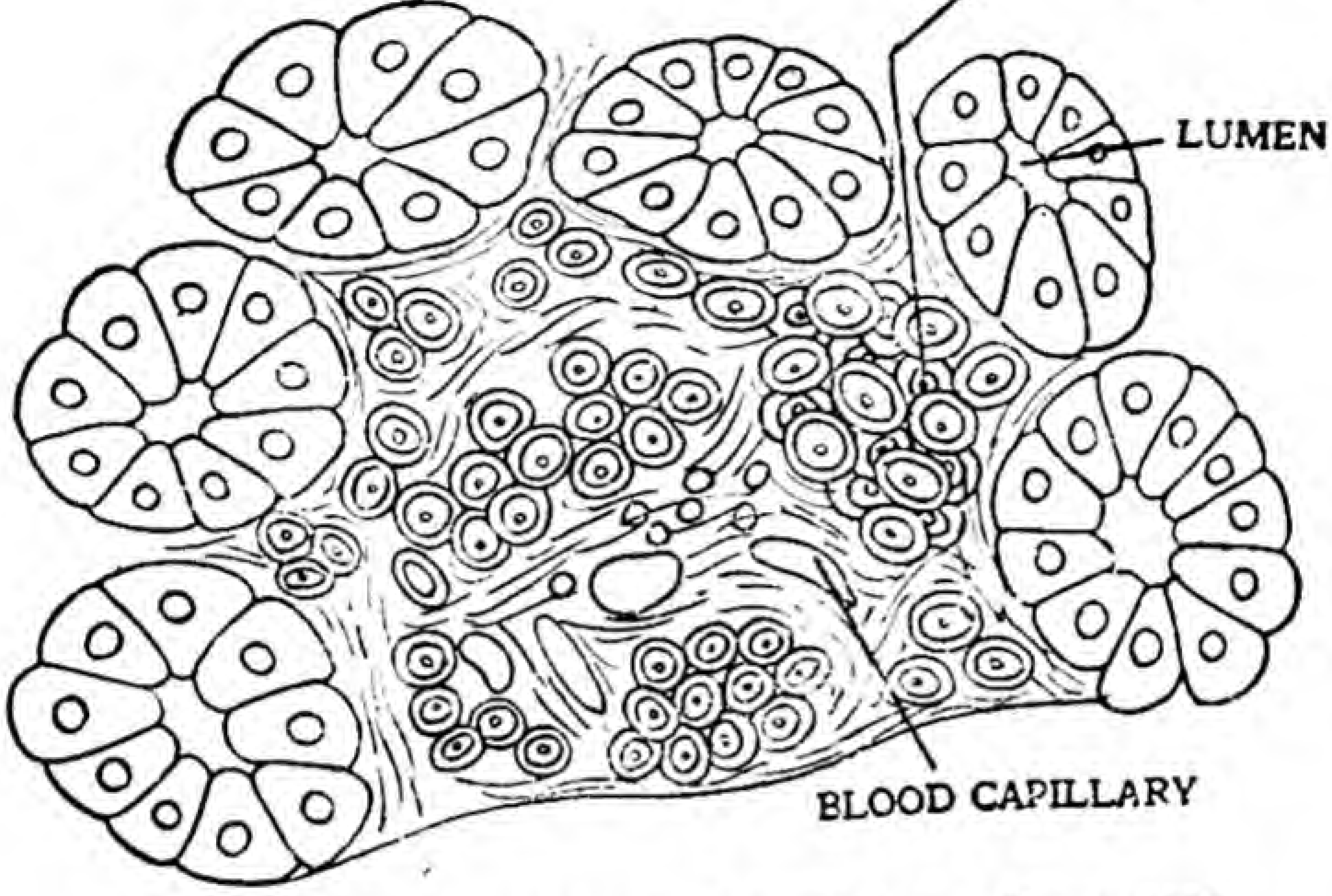


Fig. 5.31. A part of a section of pancreas

prominent nuclei and secrcte the pancreatic juice. The pancreatic juice helps in the digestion of proteins, fats and starches. The cavities of the adjacent lobules join together and open into fine ductules lined by epithelial cells. The ductules in turn unite and form the **pancreatic ducts.** The latter open into the **bile-duct.**

Groups of small closely-packed cells, termed the **Islands of Langerhans**, occur here and there in the connective tissue present between the lobules. They secrete an important hormone, the **insulin**. The hormone enables the liver to store sugar as glycogen, and also regulates the oxidation of sugar in the tissues.

Lung. The wall of the lung is very thin (Fig. 5.32), Its inner surfnce bears a network of low ridges or **septa**, which enclose shallow depressions or **alveoli**. The wall is composed of three layers : **peritoneum, connective tissue** and **ciliated epithelium**. The peritoneum covers the lung externally. It is protective in function. It consists of thin cells. The connective tissue is inside the peritoneum. It contains unstriated muscle-fibres and blood-capillaries. Besides supporting the blood-vessels, it provides elasticity to the lungs. The ciliated epithelium covers the connective tissue internally. Amongst the ciliated cells are found mucus-secreting gland cells. The mucus secreted by these cells keeps the inner surface of the lung moist for the absorption of oxygen. The inner epithelium of the lung is, thus, secretory and absorptive in function.

Blood-vessels. Blood-vessels are of three types : **arteries, veins** and **capillaries.**

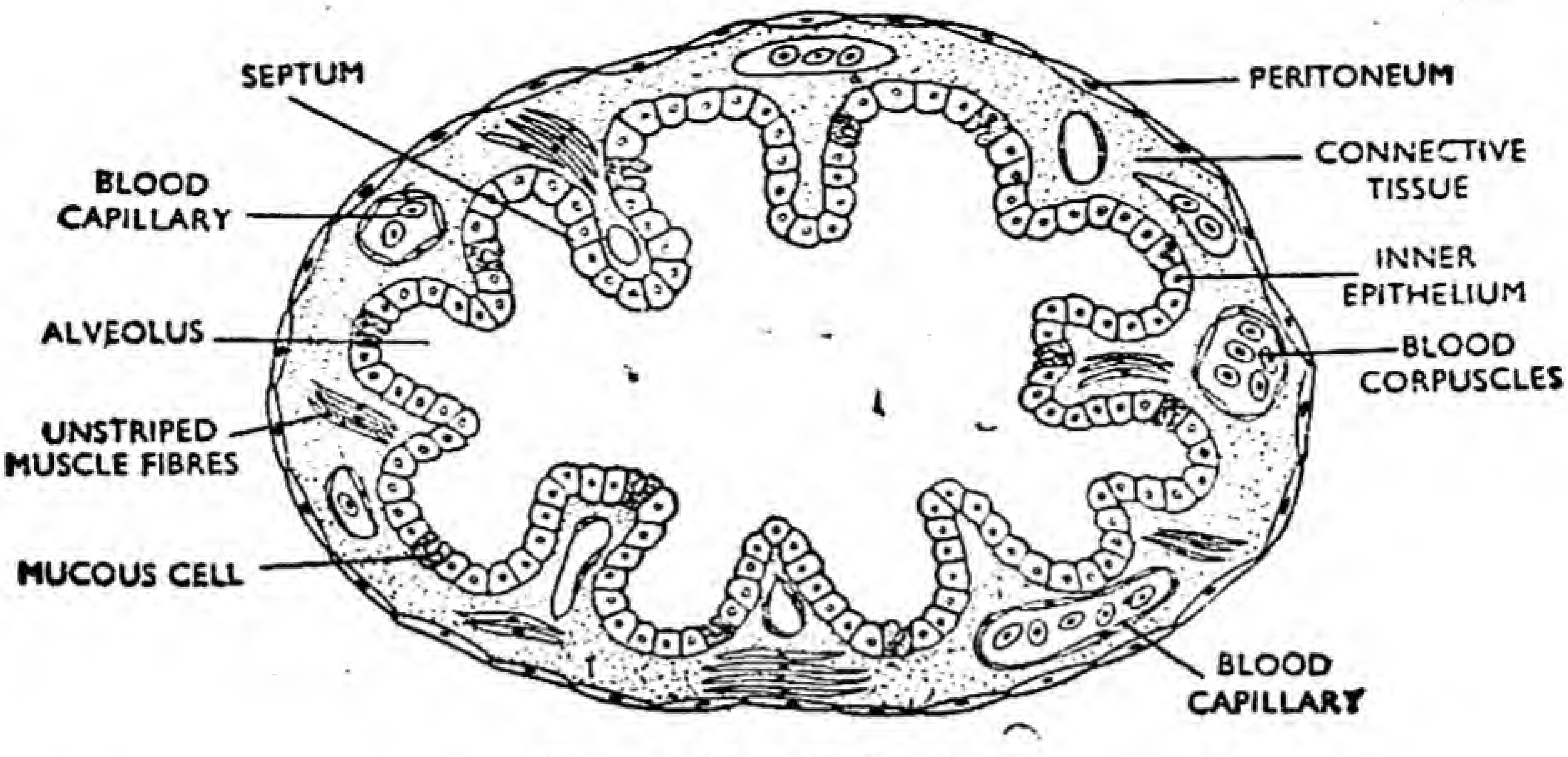


Fig. 5.32. T.S. Lung

(*a*) **Artery.** The wall of an **artery** (Fig. 5.33 left) is formed of three coats : inner, middle and outer. The inner coat is called the **tunica interna** or **intima.** It has a layer of cells, the **endothelium,** lining the cavity of the artery and a layer of elastic tissue on the outside. The endothelial cells are flattened and are elongated along the length of the artery. The elastic tissue is often in the form of a fenestrated membrane. The middle coat is called the **tunica media**. It is muscular in nature. It consists of smooth or unstriped muscle-fibres arranged in circular

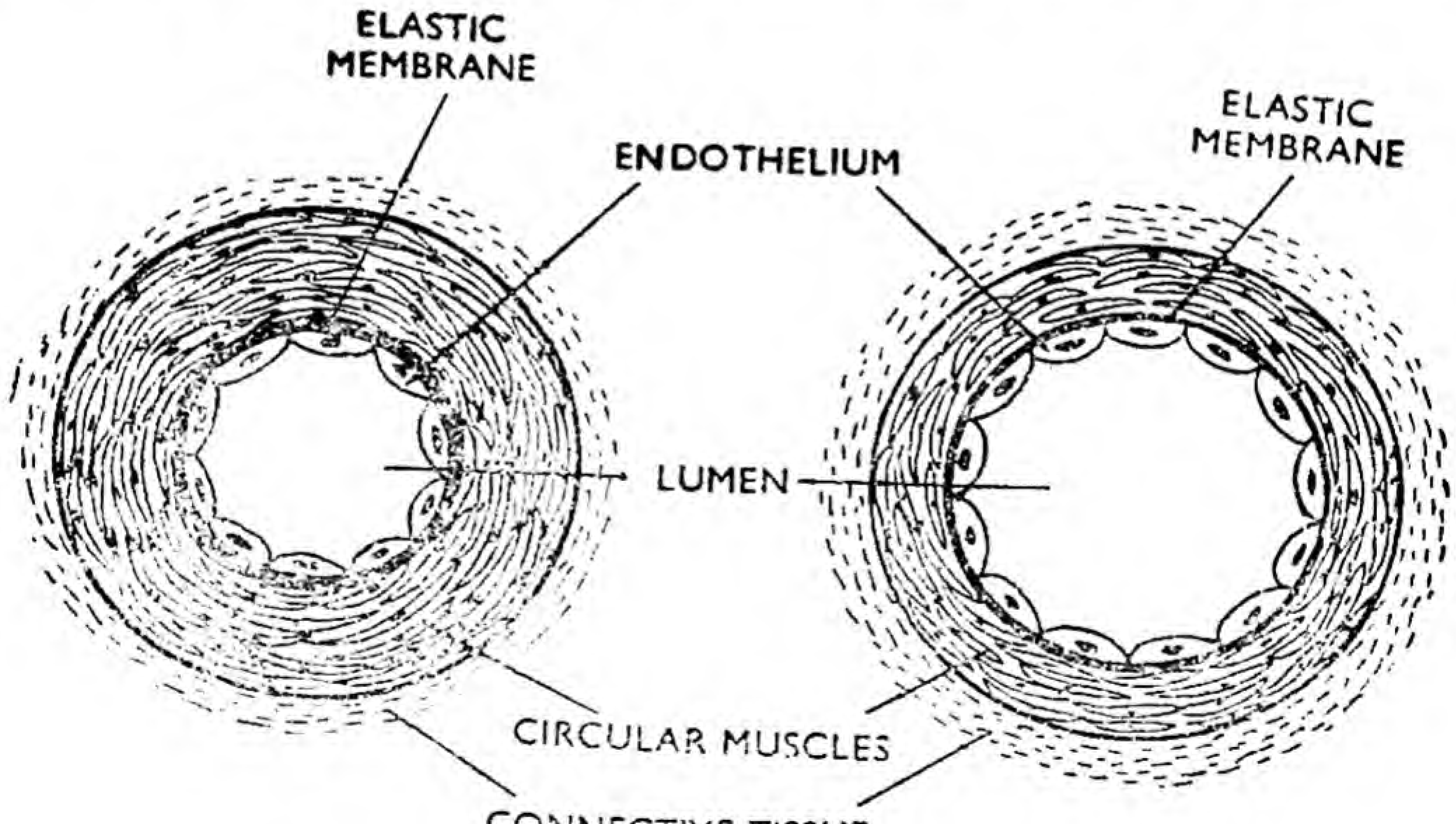


Fig. 5.33. T.S. Artery (left) and vein (right)

manner. The larger arteries like arota and its immediate **branches** contain a good deal of elastic tissue mixed with the muscle-fibres in the middle coat. The outer coat is called the **tunica externa** or **adventitia.** It consists of areolar connective tissue with longitudinally arranged white and yellow fibres. This coat is quite tough and imparts strength **to the**

artery. It also prevents its undue expansion. Its outer limit is not clear and merges with the surrounding connective tissue.

(*b*) **Vein**. The wall of a **vein** (Fig. 5.33 right) is formed of the same layers as that of an artery but shows a few differences. In the inner coat, the elastic tissue is poorly developed and the endothelial cells are less elongated. The middle coat is much thinner due to fewer muscle and elastic fibres. The outer coat is better developed than in the artery. A vein, thus, has a thinner, less elastic, but stronger wall and a wider cavity than an artery of the same size.

(*c*) **Capillary**. Wall of a capillary (Fig. 5.34) is extremely thin. It consists only of a single layer of cells or endothelium The thin walls of the capillaries permit the exchange of foods, gases, secretions and waste materials between the blood and the cells.

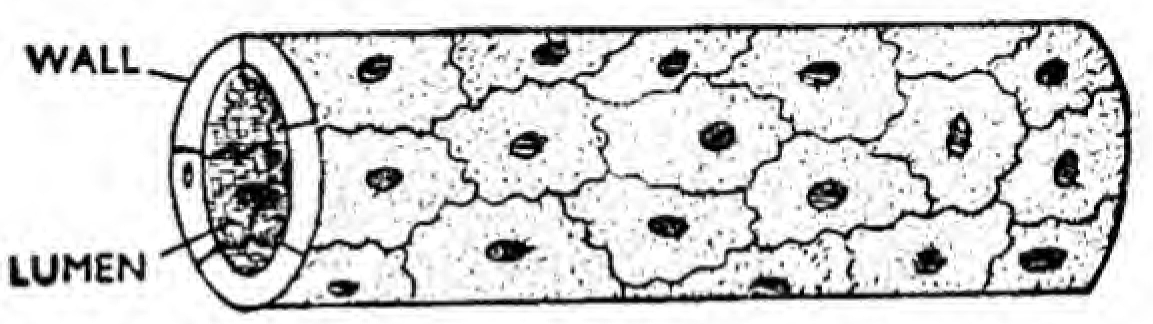


Fig. 5.34. T.S. Capillary

Spleen. The spleen is a small rounded structure of a dark-red colour. It is attach-

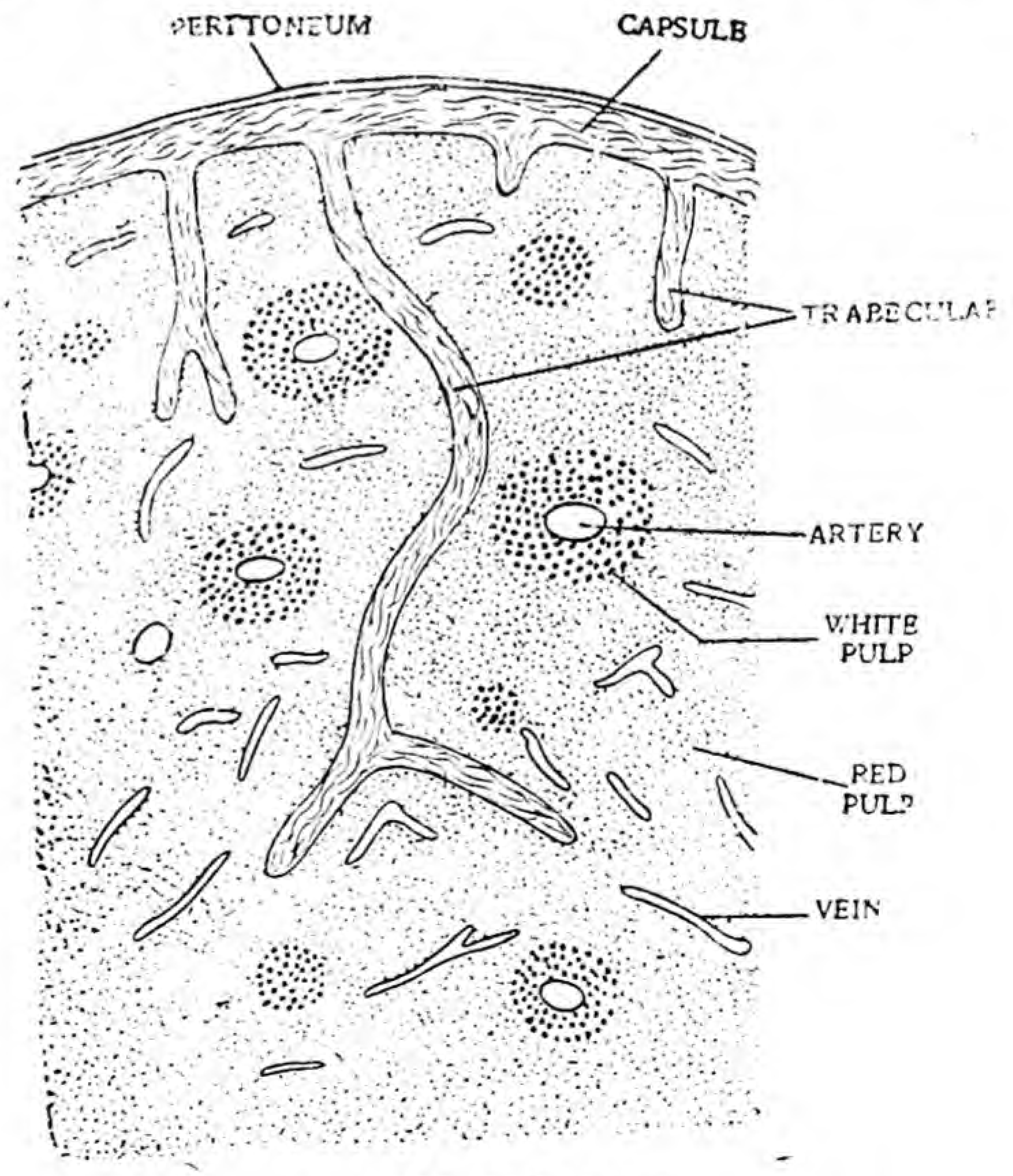


Fig. 5.35. T.S. Spleen

ed to the mesentery by one end, the **hilus**. It consists of a

soft pulpy substance surrounded by an elastic wall or **capsule** (Fig. 5.35). The capsule is composed of a dense fibrous connective tissue containing numerous elastic fibres and many smooth muscle-fibres. The capsule is covered externally by a layer of flattened cells, the **peritoneum**. From the inner surface of the capsule arise a number of strands, the **trabeculae**, which extend into the pulpy substance. The trabeculae resemble the capsule in structure and divide the spleen into compartments or **lobules**. Artery, vein and nerve pass through the hilus and extend for some distance in the trabeculae before entering the pulp. The pulpy substance is of two types ; the **white pulp** and the **red pulp**. The red pulp forms the bulk of the pulpy substance in which are scattered small patches of white pulp. Both the pulps are formed of **reticular tissue*** and **splenic cells**. In the red pulp the recticular tissue is less dense and contains many free erythrocytes, which give it red colour. In the white pulp, the recticular tissue is dense and contains white corpuscles. Many of the splenic cells act as phagocytes and destroy the red corpuscles.

The spleen is a very important organ as it serves many functions. It stores red blood-corpuscles and releases them when required. It destroys the worn out corpuscles and foreign germs. It also produces new corpuscles. An endocrine function has also been assigned to it, but the nature of its hormone is not definitely known.

Kidney. The kidney is composed of many minute and coiled tube-like structures called the **uriniferous** or **renal tubules** (Fig. 5.36). These tubules are held together by connective tissue and are enveloped by a

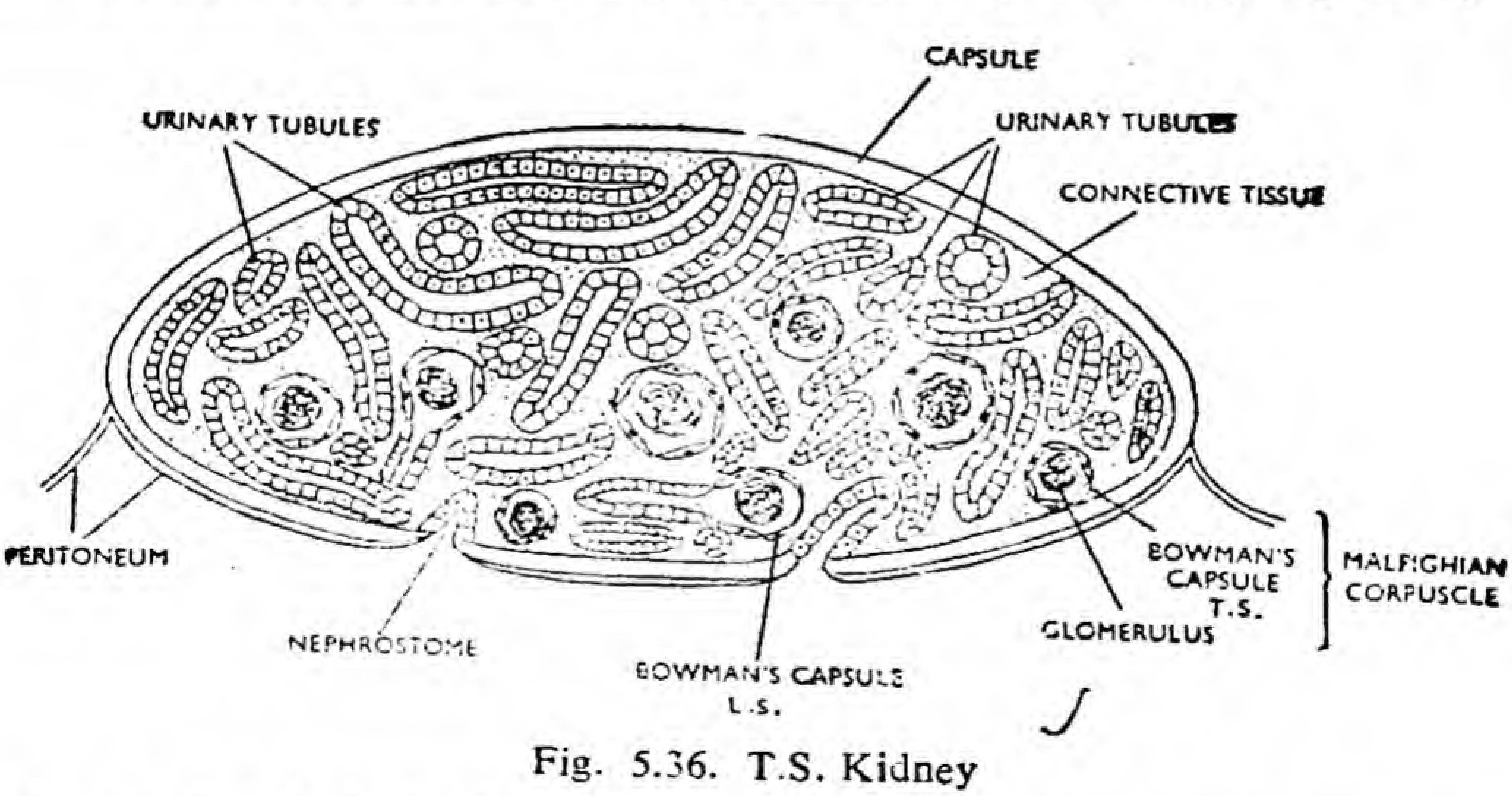


Fig. 5.36. T.S. Kidney

capsule. Each tubule is closed at one end, while the other end opens into a large tube, the **collecting tube** (Fig. 5.37). The closed end is enlarged and depreseed to form a double-walled cup called the

*Recticular tissue is a modified connective tissue in which the intercellular substance is largely replaced by lymph ; white fibres form a loose network and elastic fibres are few or none.

Bowman's capsule. The latter encloses a bunch of blood-capillaries called the **glomerulus.** The Bowman's capsule and the glomerulus together from the **Malpighian body.** The Bowman's capsule is lined with flattened cells. The ventral wall of the kidney is perforated by a number of minute funnel-shaped apertures, the **nephrostomes.** The latter connect the coelom with some of the veins inside the kidney for the passage of waste materials from the coelomic fluid.

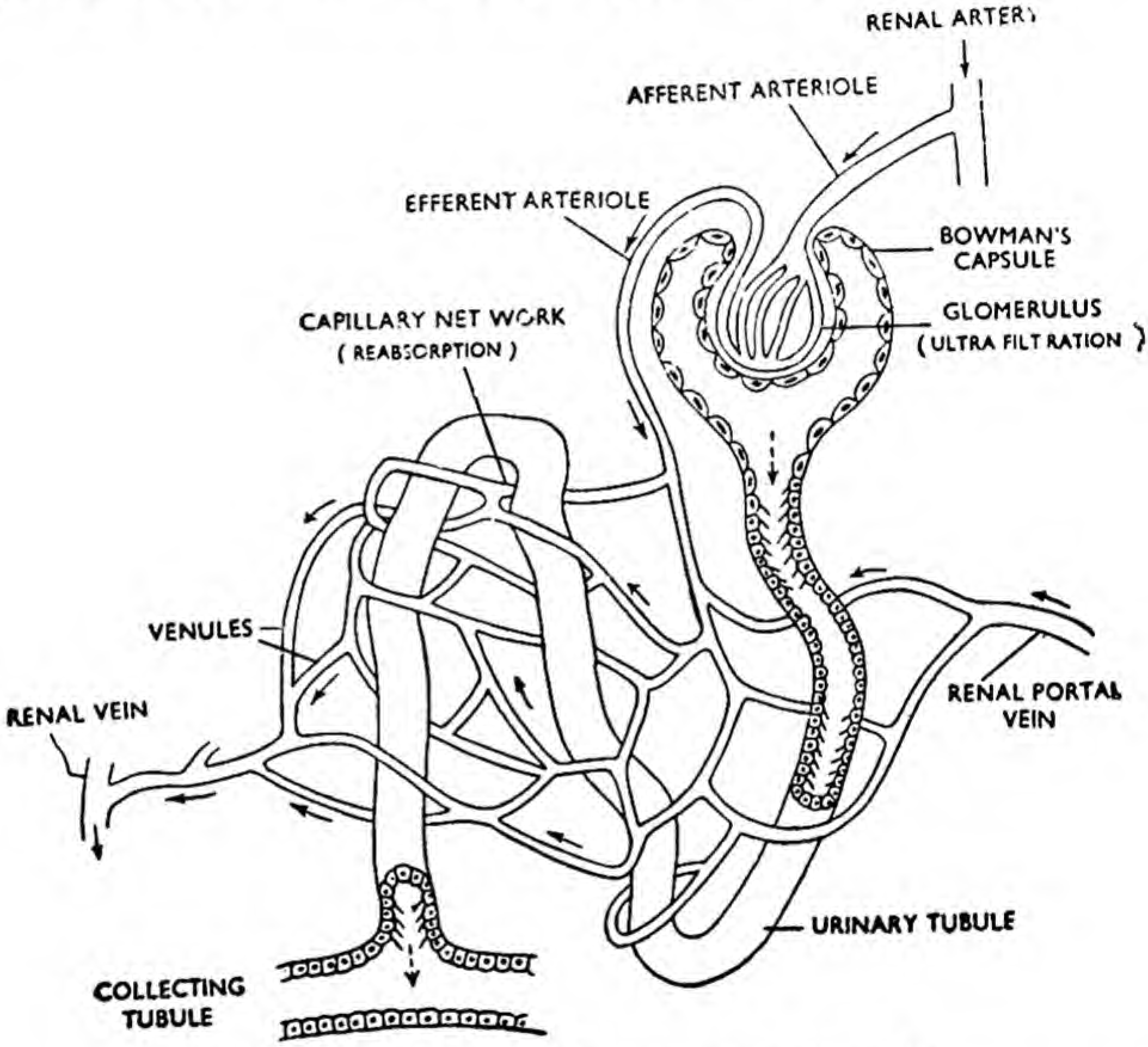


Fig. 5.37. A uriniferous tubule and its blood-supply

The kidney receives blood from renal arteries and renal portal vein. Each renal artery on reaching the kidney breaks up into small branches. Each branch enters the Bowman's capsule, where it forms the glomerulus. This branch is called the **afferent vessel.** The blood from the glomerulus is taken away by the **efferent vessel,** which forms a capillary network around the uriniferous tubule. The renal portal vein also forms capillaries round the tubule. The blood from the tubules is drained away by renal veins.

The process of urine formation is discussed in chapter 23.

Ovary. The ovary (Fig. 5.38) is a hollow sac of irregular shape. Its wall is thin and folded as to divide its cavity into compartments or lobes. The wall is formed of connective tissue or **stroma** containing blood-vessels and nerves. It is lined internally by a layer of flattened

cells and is covered externally by **germinal epithelium.** The latter is simply a modified peritoneum. The germinal epithelium buds off cells called the **oogonia** from which arise ova or eggs through a complicated process of **oogenesis** (Fig. 4.8). Groups of oogonia form the ovarian follicles, which form small projections on the surface of the ovary. One of the oogonia in each follicle develops into a mature **ovum** and others form

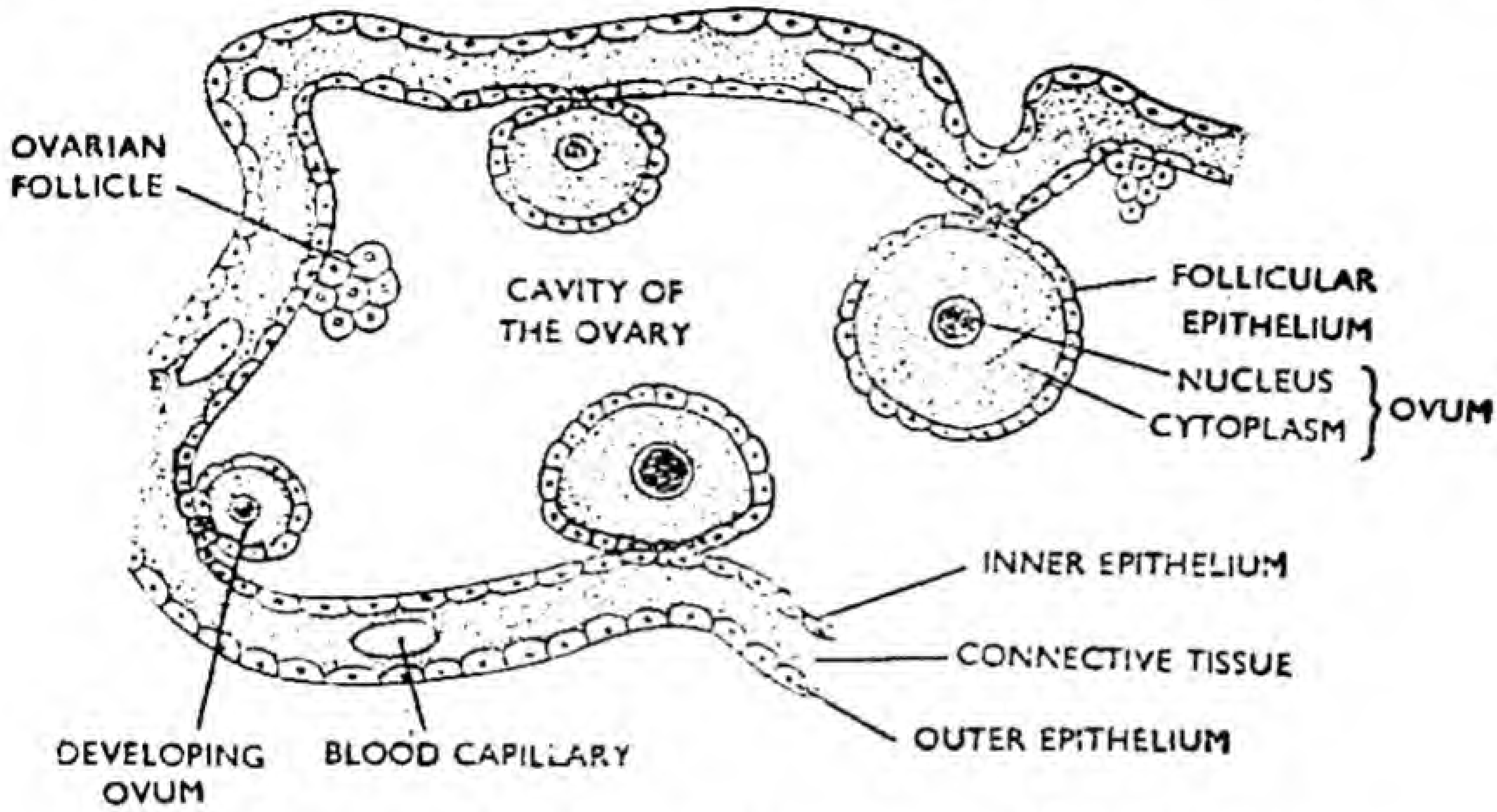


Fig. 5.38. A part of section of frog's ovary

the outer layer of the follicle. Round the ovum there is a thin membrane, the **vitelline membrane**. This membrane is secreted by the ovum itself. When the ova are mature, the follicles rupture and the ova are released into the body-cavity. This process is called **ovulation.** The ovum is a rounded cell containing a **nucleus** at its centre. The cytoplasm is laden with yolk granules, which are both albuminous and fatty in nature. These granules are the food of the developing embryo. The granules are localised at one pole of the ovum. It is called the **vegetative pole**, the other pole is the **animal pole**. When an ovum tends to mature, the animal pole becomes black on account of the black pigment deposited on its outside. The vegetative pole, however, remains white.

Testis. The testis is composed of many microscopic tubules called the **crypts** (Fig. 5.39). These crypts are held together by connective tissue, which contains blood-capillaries and nerves. The crypts are wrapped in a fibrous **capsule.** The latter is covered by **peritoneum**. The wall of a crypt is formed of a layer of actively dividing cells, the **germinal epithelium** The epithelium produces rounded cells called the **spermatogonia** (Fig. 4.10). The latter pass into the cavity of the crypt and are transformed by an elaborate process of **spermatogenesis** into the male germ cells known as the **spermatozoa** or **sperms.** A sperm consists of a small rod-like head having the nucleus and a long whip-like cytoplasmic tail (Fig. 5.40).

The crypts open into a narrow cavity in the centre of the testis. **This** cavity communicates with the kidney of its side **by means of small**

ducts called **vasa efferentia.** These ducts carry sperms from the testis into the collecting tubules of the kidney, where they mix with the urine and pass out through the urinogential duct.

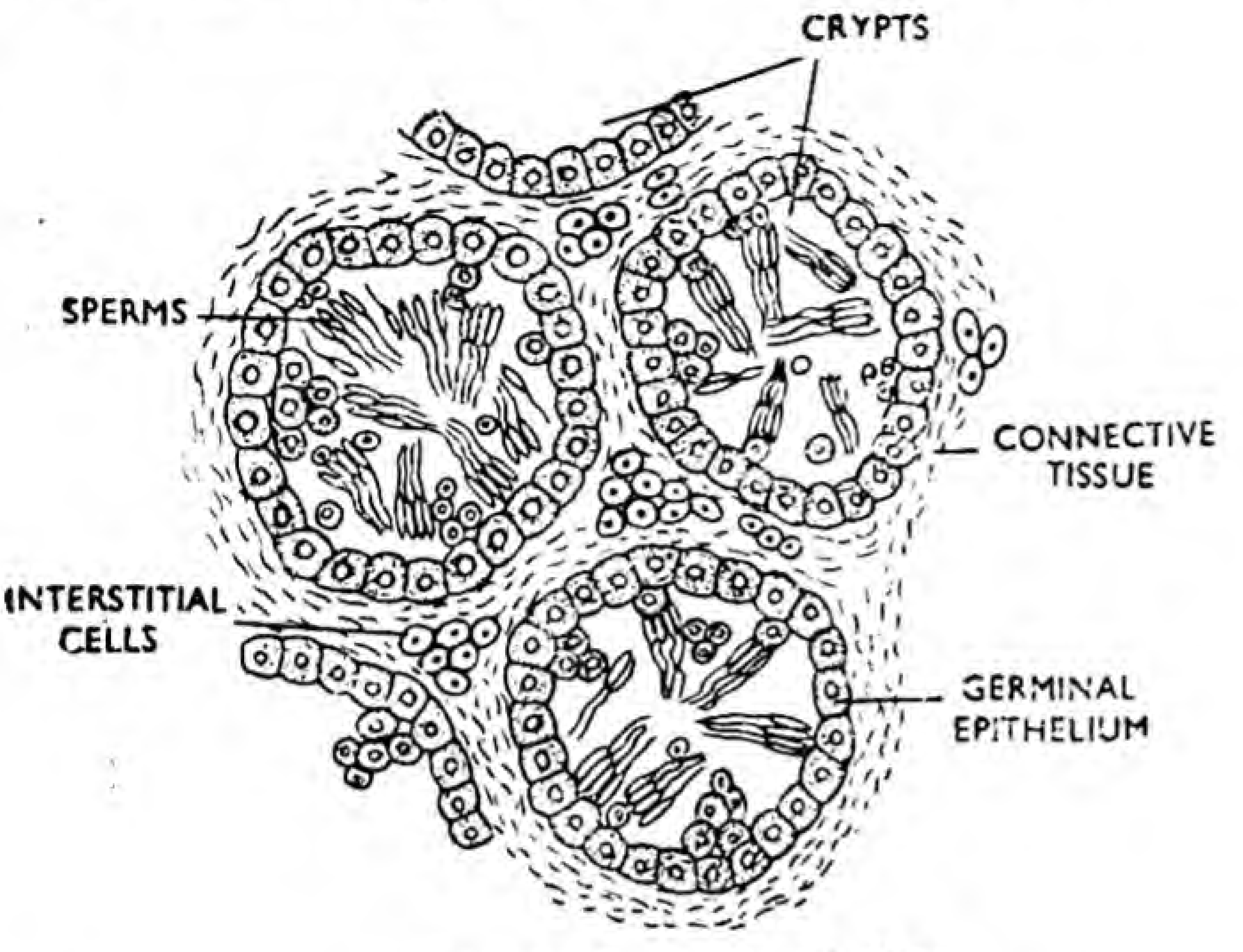


Fig. 5.39. Testis of frog

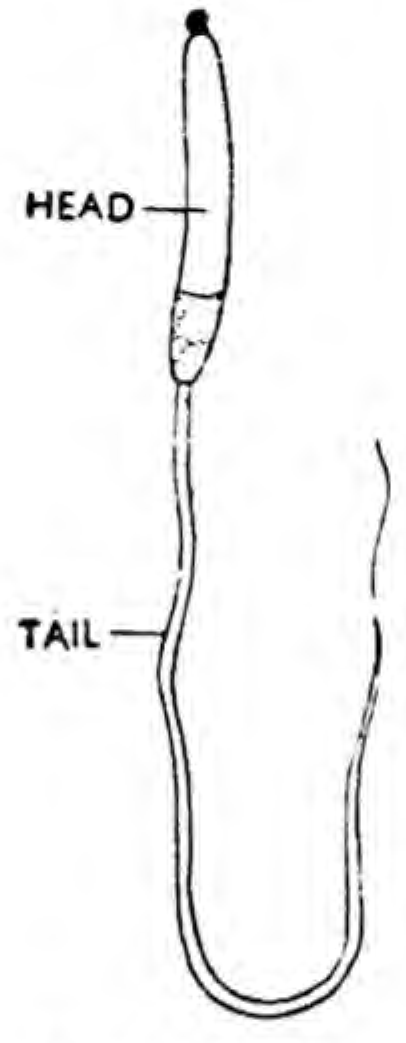


Fig. 5.40. Spermatozoon of frog

The connective tissue lying between the crypts contains here and there special cells called the **interstitial cells**. They secrete a hormone, which is responsible for the secondary sexual characters.

Retina. Retina is the innermost coat of the eye-ball. It is composed of four main layers, each containing a different type of cells (Fig. 5.41) Beginning from outside inwards, these layers are :—

(*i*) **Layer of Pigment Cells.** This is the outermost layer of the retina and lies in contact with the choroid. It is continued forwards over the posterior surface of the iris. It consists of cubical cells containing granules of a dark-brown pigment. The inner surface of the cells is fringed with protoplasmic processes.

(*ii*) **Layer of Receptor Cells.** The receptor cells of the retina are sensitive to light and are known as the **visual cells** or **photoreceptors,** They are greatly elongated and are arranged with their long axes perpendicular to the surface of the retina. They are of two types : the **rod cells** and the **cone cells.**

(*a*) **Rod Cell.** A rod cell (Fig. 5.42) consists of an outer rod-like part, **the retinal rod**, and an inner thread-like part, the **rod fibre.** The retinal rod shows two segments : the outer cylindrical segment containing a purplish-red pigment, the **visual purple** or **rhodopsin,** and the inner **slightly-bulged** segment. The rod fibre is swollen at one place to house **the nucleus** and ends internally in a small knob.

(*b*) **Cone Cell.** A cone cell (Fig 5.42) consists of an outer broad **tapering part, the retinal cone,** and an inner slender part, the **cone fibre.**

The retinal cone further shows two segments : the outer conical segment and the inner bulged segment. The cone fibre is enlarged externally to house the nucleus and ends internally into a number of fine branches.

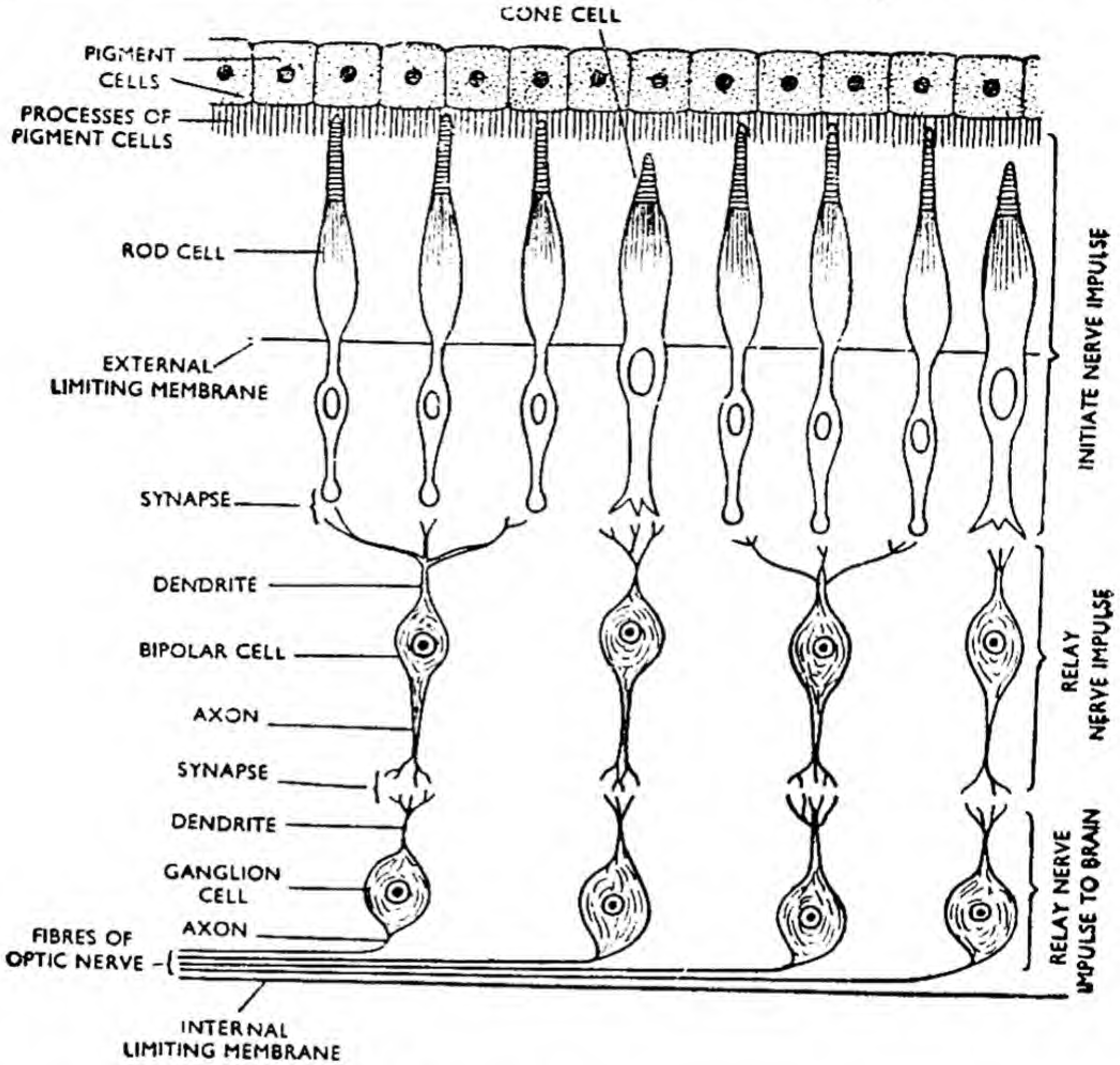


Fig. 5.41. V.S. Retina of frog (Diagrammatic)

Rod and cone cells are not evenly distributed over the retina. A small depressed area, the **fovea centrails,** has only cone cells. It lies right at the posterior pole of the eye-ball. It is the point of maximum vision.

(*iii*) **Layer of Bipolar Nerve-cells.** These are nerve-cells with large nuclei. Each cell has two processes : the **axon** on one side and the **dendron** or **dendrite** on the other. The dendrons of all the cells extend outward and form **synapses** with terminations of rod and cone fibres. Synapse is a close juxtaposition of processes of the nerve-cells without any organic connection. The axons of the bipolar cells extend inwards to form synapses with the dendrons of the next layer of cells.

(*iv*) **Layer of Ganglion Cells.** These are large nerve-cells, each with a large axon and a dendron. The dendrons, as stated above,

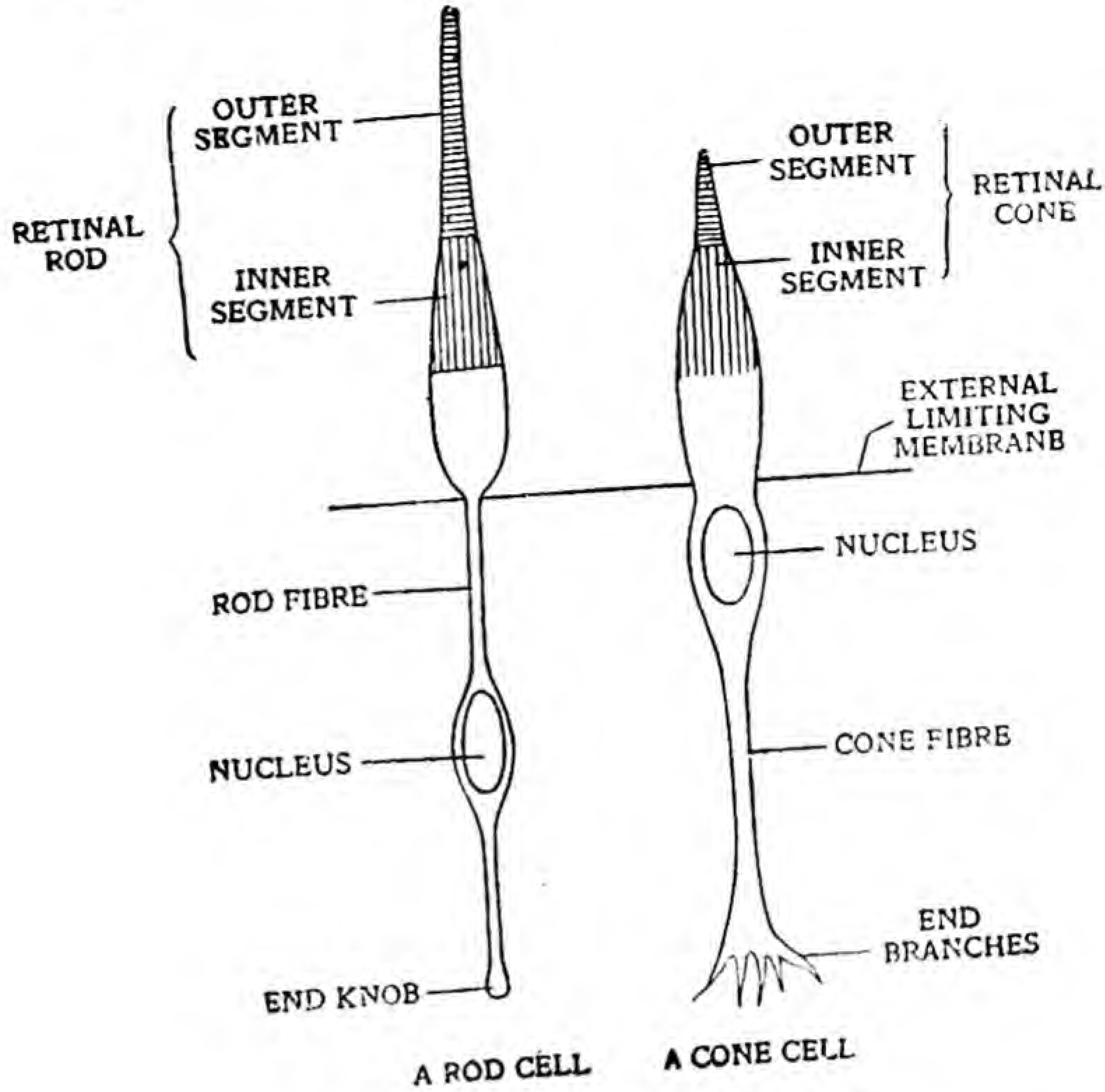


Fig. 5.42. A rod and a cone cell

extend outwards and form synapses with the axons of the bipolar cells. Axons of the ganglion cells run backwards over the inner surface of the retina. They converge at the back of the eyeball, pierce the retina, acquire medullary sheaths and form the optic nerve. This point is called the **blind spot** as it lacks visual cells and receives no stimuli.

A very thin membrane, called the **internal limiting membrane**, covers the inner surface of the retina. Another similar membrane, the **external limiting membrane**, supports the layer of receptor cells, which pierce to extend on its both sides.

Certain undifferentiated cells, called the **neuroglia cells**, fill up the spaces between the visual and nervous cells of the retina. They, thus, serve the supporting and packing function.

The receptor cells receive the visual stimuli and relay the nerve-impulses so generated to the optic nerve through the bipolar and ganglion cells. The optic nerve transmits the impulses to the brain.

The cone cells function during bright light and are responsible for colour vision. The rod cells work in reduced light. Rods contain visual purple, which is necessary for their proper functioning. Bright light fades away the visual purple and makes the rods ineffective. This is why on leaving a well-lighted room at night or on entering a dark room during daytime, one feels temporarily blind. The reason for this is the absence of visual purple from the rod cells, which are to operate in

reduced light. Soon visual purple is restored and rod cells begin to function and one starts seeing in the dark.

Man's vision is poor in the dark as his eyes have fewer rod cells. Nocturnal animals like cat, deer and owl, have rod cells in abundance and can see clearly in the dark.

Histology of the mammalian skin, bone and blood is described in chapter fifteen, sixteen and nineteen respectively.

TEST QUESTIONS

1. What is a tissue ? Name the various types of tissues and describe any two.

2. What is histology ? Give an account of Cartilage, Skeletal Muscles, Ciliated Epithelium, Blood and Medullated Nerve-fibres.

3. Explain the following terms :—

Sarcolemma, Periosteum, Perichondrium, Neuron, Neurilemma, Collagen, Elastin and Bone Marrow.

4. Draw a labelled figure of the T. S. of decalcified femur of frog.

5. Give the histological structure of the following :

Kidney, Stomach, Liver, Skin of frog, Retina, Pancreas.

6. Make labelled sketches of the following :—

T.S. Intestine of frog, T.S. Spleen, T.S. Testis.

7. Write brief notes on :—

Rods and Cones, Islands of Langerhans, Mucous Membrane, Glomerulus, Peritoneum.

8. Explain the following terms :—

Phagocytes, Oogenesis, Ultrafiltration, Acinus, Crypt, Endothelium, Reticular Connective Tissue, Nephrostome, Vitelline Membrane.

CHAPTER 6

Amoeba proteus

(The Proteus Animalcule)

Amoeba was first recorded in the year 1755 by Roesel Von Rosenhof, who described it as "the little Proteus." There are several species of *Amoeba* differing from one another in minor details. Of these, *Amoeba proteus* is selected to introduce the realm of acellular animals to the students of Biology because of its simple structure and relatively large size. Moreover, it can be easily procured from artificial culture.

Habitat and Habits

Amoeba proteus is a free-living organism. It inhabits fresh-water ponds and slow-flowing streams having a lot of decaying organic matter. It is generally found creeping on the mud at the bottom or sticking to the submerged weeds and stones. Sometimes, it slowly floats in water, waving its pseudopodia in search of some solid object.

Culture

Culture of *Amoeba proteus* is commonly prepared by keeping hay or dry leaves submerged in water at a warm airy place. Amoebae appear in this culture in two to four days. They are specially numerous in the surface scum and sticking to pieces of hay and leaves. They hatch from the cysts, which settle in water from the air.

Morphology

Form, Size and Colour. *Amoeba proteus* is a microscopic organism about 0·25 mm. in diameter. It is slightly greyish in colour. It has an irregular body, which changes its shape every moment. This habit thoroughly justifies its name (Gr. *amoibe* = change ; *Proteus* = a sea-god in Greek mythology having the power of changing its shape). The irregular and ever-changing shape is due to the formation of blunt projections from the surface of the body. These projections are called **pseudopodia**.

Plasmalemma. The body of *Amoeba* is bounded by a very thin and delicate covering. It is called the **plasma membrane** or **plasmalemma.** Electron microscope shows it to be two-layered. It has little firmness, but considerable elasticity. It possesses a good degree of power of regeneration and quickly repairs itself if injured. The plasmalemma prevents the animal sticking to the substratum, keeps the protoplasm intact and regulates the exchange of materials between the protoplasm and the surrounding water.

Protoplasm. Body of *Amoeba* (Fig. 6.1) is composed of the living matter or **protoplasm**. A small but prominent structure of specialised protoplasm, termed the **nucleus**, lies more or less in the centre of the protoplasm. The part of protoplasm outside the nucleus is known as the **cytoplasm.** The latter shows two distinct regions : the **ectoplasm** and the **endoplasm**. There is, however, no visible line of demarcation between the two regions.

1. **Ectoplasm**. The ectoplasm forms a thin, clear (non-granular), relatively firm, peripheral layer of cytoplasm. It is slightly thicker on the advancing side of the body and at the tips of the pseudopodia. This suggests that the ectoplasm has a protective function. It bears a few ridges, which make it a supporting layer also.

2. **Endoplasm**. The endoplasm forms the granular central mass, which constitutes the bulk of the animal. It occurs in two colloidal states : the outer viscid **plasmagel** underlying the ectoplasm and the inner more fluid **plasmasol**. The latter shows slow streaming movements in the living animal. The endoplasm contains, besides the nucleus and granules, a large **contractile vocuole** and a number of small non-contractile **food-vacuoles**, minute nutritive spheres representing reserve food material and variously shaped crystals representing waste matter.

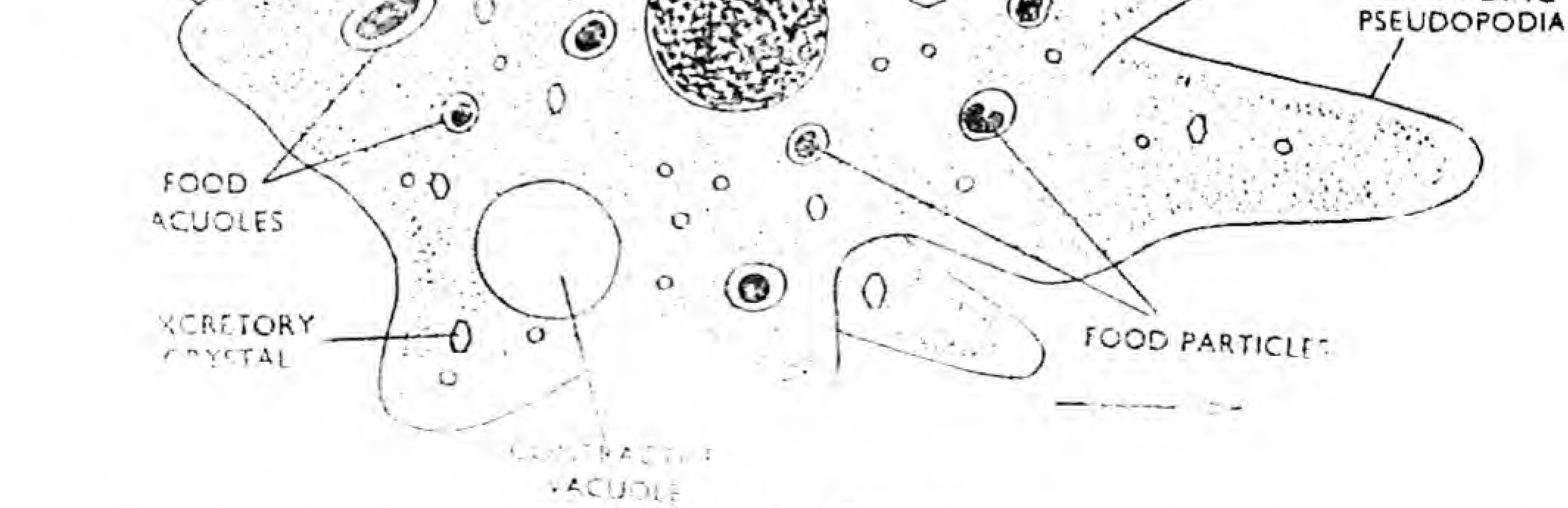


Fig. 6.1. *Amoeba proteus*

(*i*) **Nucleus**. The nucleus has the form of a biconvex disc in the young specimen, but may be folded or convoluted in the older

specimens. It is highly granular and, therefore, refractive to light. It consists of a two-layered **nuclear membrane** surrounding a large number (over 500) of **chromosomes** scattered in a fluid, the **nuclear sap**. The nucleus is not stationary. It is carried along in the currents of the plasmasol. The nucleus controls all the vital activities of the body. It is shown by the fact that the denucleated animal ultimately dies.

(*ii*) **Contractile Vacuole**. The contractile vacuole is a prominent, spherical, bubble-like body, which contracts and disappears at more or less regular intervals. Its position is not fixed. It keeps on moving with the streaming plasmasol between the nucleus and the end of the body farthest from the advancing side.

(*iii*) **Food-Vacuoles.** The food-vacuoles vary in size and number. They are spherical and enclose the ingested food-particles and water. Food undergoes digestion in these vacuoles.

Physiology

Though acellular, *Amoeba* exhibits all the activities of life. It moves about, nourishes itself, respires, grows, excretes, responds to stimuli and reproduces.

Locomotion. *Amoeba*, like other animals, moves in order to approach a food-particle or to creep away from the enemies and unfavourable environments. The movements are brought about by pseudopodia. Being thick, blunt and composed of both ectoplasm and endoplasm, the pseudopodia are known as **lobopodia**. Several theories have been put forward about the formation of pseudopodia. Of these, the **gel-sol theory** put forward by Mast (1930) and supported by Rinaldi and John (1963) seems to be essentially correct.

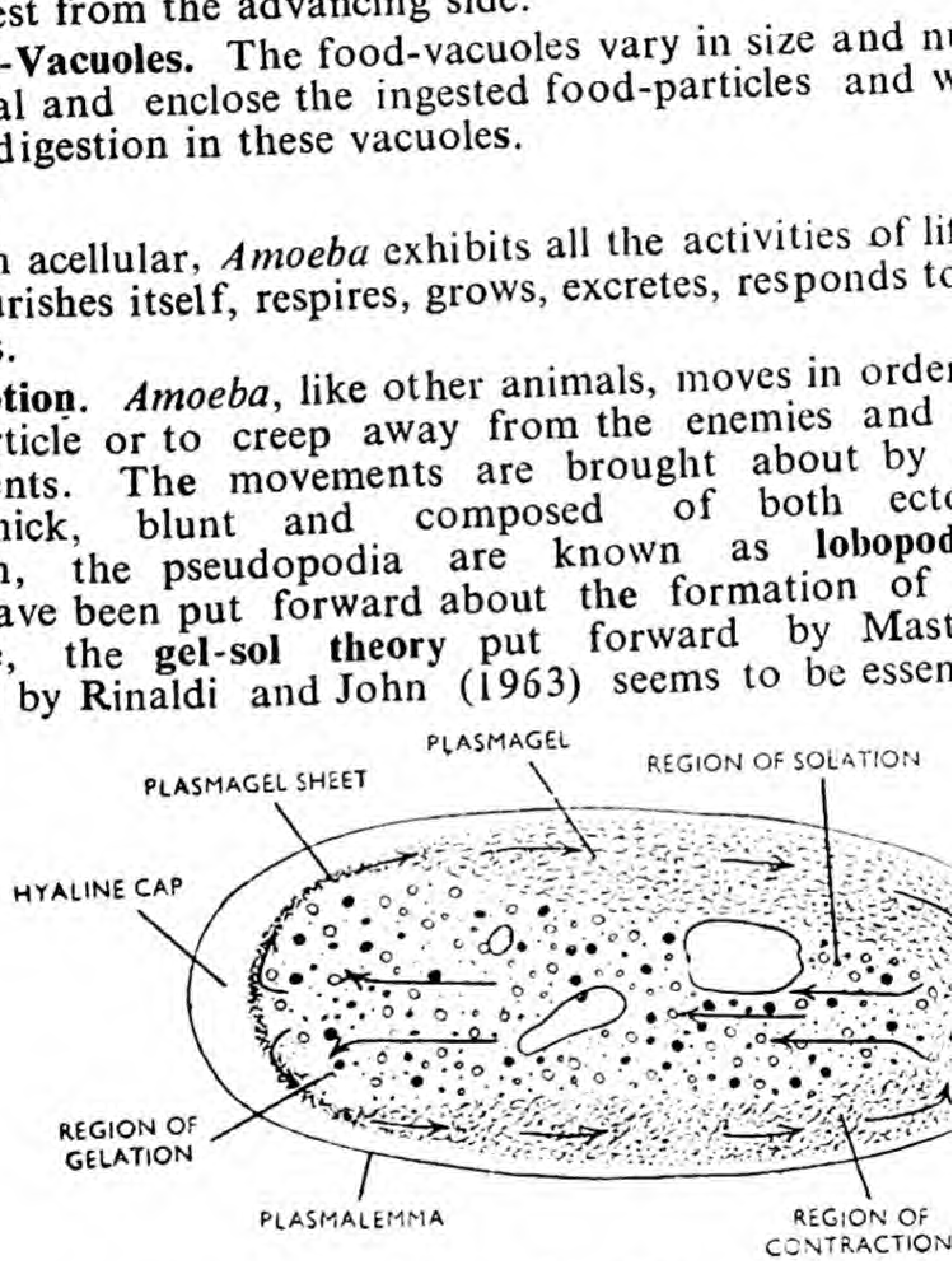


Fig. 6.2. Diagram showing the changes that occur in the cytoplasm during locomotion of *Amoeba*

According to this theory, the plasmagel changes to plasmasol and vice-versa for the formation of pseudopodia. At the advancing or anterior end, the plasmagel partially changes to a sol state (Fig. 6.2) and thus becomes much thinner, softer and weaker than the rest of the plasmagel. The plasmagel of the opposite or posterior end contracts and causes a hydraulic pressure on the plasmasol within. Due to the hydraulic pressure on it, the plasmasol is pushed forward towards the softened

plasmagel which, being weak, cannot withstand the pressure and develops an outward bulge to receive the plasmasol. As the plasmasol enters it, the bulge steadily elongates. At the periphery of the bulge, the plasmasol changes into gel state. Thus, a tube of plasmagel with a core of plasmasol and a covering of ectoplasm is formed and this is the pseudopodium. The plasmagel at the rear end, at its junction with the plasmasol, continuously changes into the plasmasol that flows forward. This results in the withdrawal of pseudopodia from the posterior side and ensures continuous supply of plasmasol to the developing pseudopodia at the advancing end. By forming pseudopodia continually in one direction, *Amoeba* slowly changes its position as well as its shape. The flowing movements of *Amoeba* are discribed as the **amoeboid movements.** *Amoeba* can cover a distance of about 25 mm. per hour by these movements. All the pseudopodia may not be in one plane. A few short pseudopodia are formed on the ventral side so that *Amoeba* appears to be walking on their tips (Fig. 6.3).

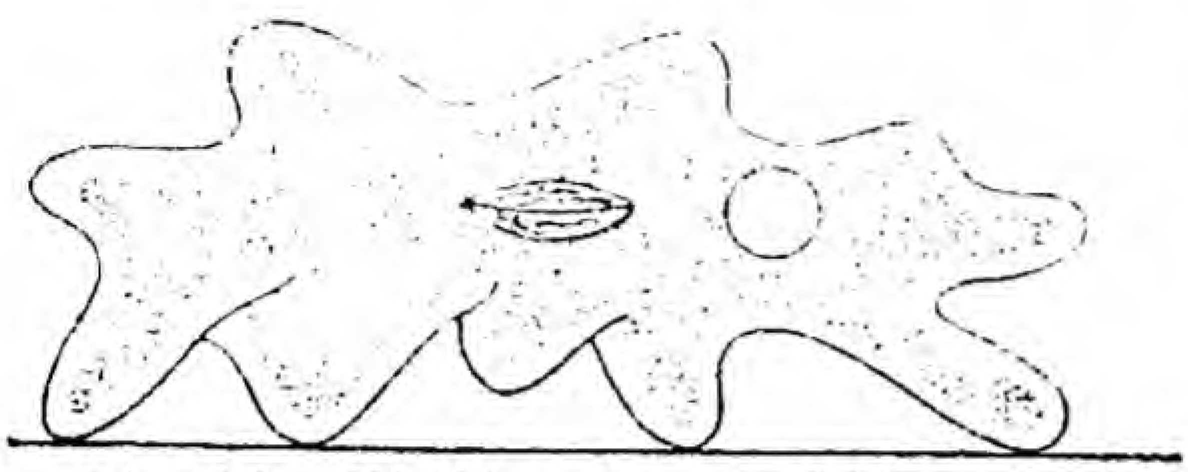


Fig. 6.3. Walking *Amoeba* (side view)

Nutrition. *Amoeba proteus* is **holozoic**, *i.e.* takes solid organic food. Its food consists of acellular plants like bacteria and diatoms, other protozoans like flagellates and ciliates, small fragments of multicellular organisms and organic debris. It is, thus, **omnivorous** in diet. It is able in some way to select its food, prefering diatoms and small flagellate *Chilomonas*.

Ingestion or intake of food can occur at any point on the body as there is no mouth in *Amoeba*. It is captured with the help of pseudopodia. On approaching a food-particle, *Amoeba* extends a cup-shaped pseudopodium, the **food-cup,** around it (Fig. 6.4). The food-cup soon closes on other side of the food-particle. The food-particle is now inside the body. A droplet of water is also engulfed along with the food-particle. This droplet of water surrounds the food-particle and forms the non-contractile **food-vacuole.** The food-vacuole is bounded by the plasma membrane and ectoplasm, which were formerly parts of the corresponding structures covering the entire body. The entire process of capturing a food-particle takes only a minute or two.

Digestion of food takes place inside the food-vacuoles which, thus, serve as temporary stomachs. Digestive enzymes are secreted into the food-vacuoles by the surrounding cytoplasm. The enzymes gradually digest the food, *i.e.* convert it into a diffusible form. Contents of the food-vacuoles are first acidic and then alkaline in reaction. This corresponds to the acidic phase of digestion in the stomach and alkaline in the intestine in higher animals including man. The enzymes reported from *Amoeba* include the **amylase,** which converts the starches into sugars, **lipase** that changes fats into glycerine and fatty acids, **proteinase,**

which breaks proteins into peptides and **dipeptidase** that transforms the peptides into amino-acids.

The soluble foods resulting from digestion pass through the membrane of the food-vacuole into the surrounding cytoplasm. This is called **absorption** of food. As digestion and absorption proceed, the food vacuoles decrease in size till only indigestible matter is left in them.

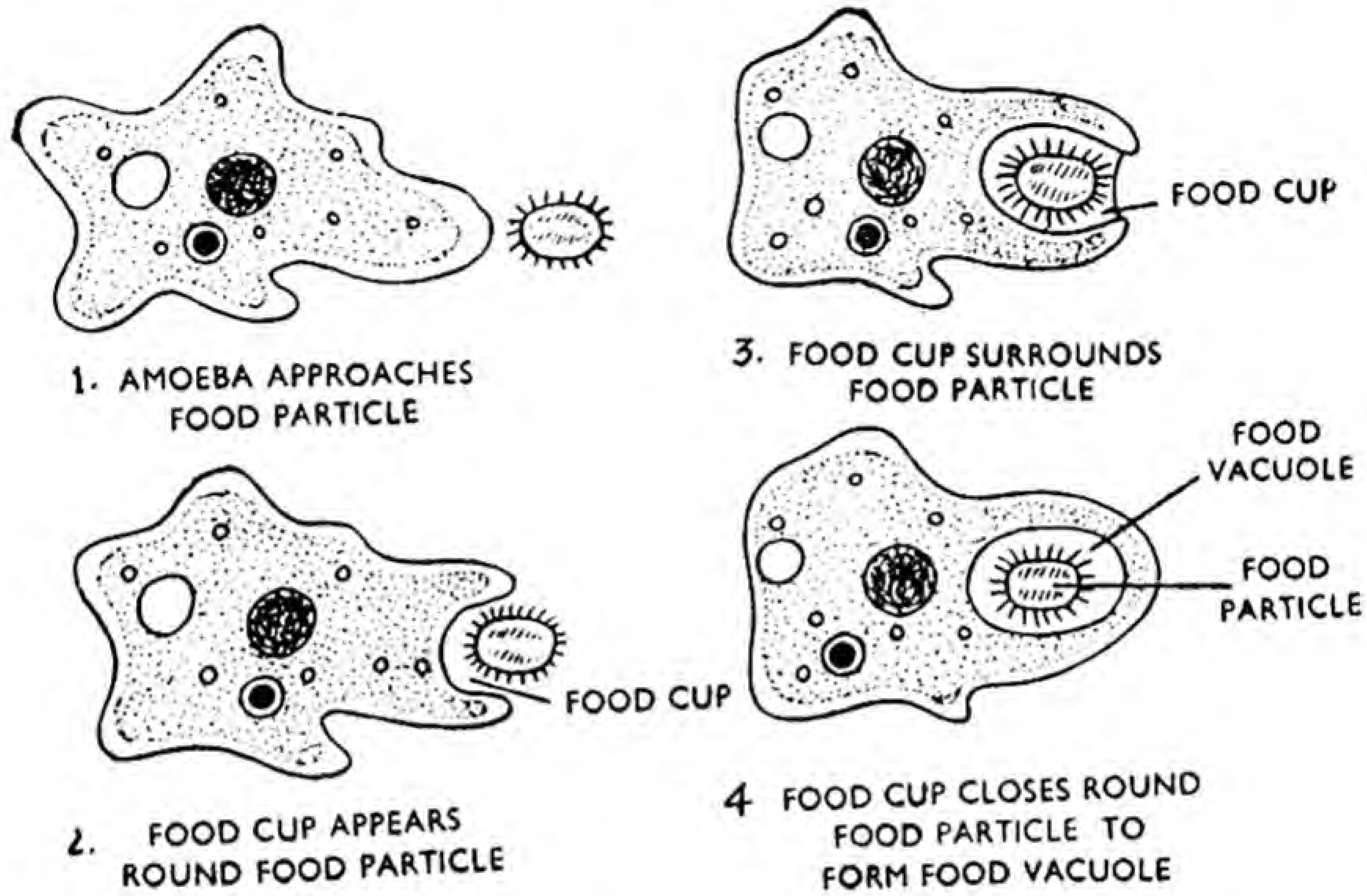


Fig. 6.4. Ingestion of food by *Amoeba*

The soluble foods diffusing into the cytoplasm are synthesized into protoplasm. This is called **assimilation** and results in growth. Some food is synthesized into storage products like glycogen and fats. Synthesis occurs under the influence of enzymes.

Egestion or elimination of indigestible food also occurs at any point on the surface of the body, as there is no regular anus. The indigestible matter or faeces left in the food-vacuole is denser than the surrounding endoplasm and, therefore, lags behinds in the endoplasmic currents. This vacuole finally comes in contact with the plasmalemma at the hind end of the animal. The plasmalemma ruptures at this point and the faeces goes out as the animal moves ahead. Plasmalemma soon gets repaired to prevent the outflow of endoplasm.

Respiration. Respiration comprises the absorption of oxygen and liberation of carbon dioxide. In *Amoeba* respiration or gaseous exchange takes place through the general surface of the body. The water where *Amoeba* lives contains some oxygen in dissolved state. This oxygen comes in the water from the atmosphere or from the aquatic plants. The partial pressure of the dissolved oxygen is more than that in the body of *Amoeba*. Therefore, oxygen from water passes into the organism through the plasma membrane by a process of **diffusion**. In the cytoplasm, there occurs oxidation or physiological burning of food-materials like carbohydrates, lipids and even proteins, under the influence of enzymes. In

this process foods break down into simpler substances like water, carbon dioxide and nitrogenous wastes. This is accompanied by the release of energy, which is used by *Amoeba* in its various activities. The carbon dioxide formed in the body has a greater partial pressure than that in the outside water. Consequently, it leaves the body by diffusion through the plasma membrane.

Growth. Two processes occur side by side in the body of *Amoeba*. New protoplasm is built up from the food (**anabolism**) and the protoplasm is also broken down for releasing energy (**katabolism**). These processes together constitute the **metabolism**. Normally, anabolism outweighs katabolism so that protoplasm is gradually added to the body. This results in growth. On attaining its maximum size, *Amoeba* divides into two.

Excretion. Excretion is the elimination of nitrogenous waste materials from the body. In *Amoeba*, these materials are mainly ammonium compounds. They are isolated from the cytoplasm by crystallization in small vacuoles. Young *Amoeba*, when liberated from the cyst, is free from excretory crystals. The crystals soon appear and increase in size with the growth of *Amoeba*. They are got rid of with the residual cytoplasm during multiple fission.

Some nitrogenous waste matter is also eliminated through the general surface of the body by diffusion. Probably, a part of excretion occurs through the contractile vacuole too.

Osmoregulation. Osmoregulation means keeping the water-contents of the cell constant. The cytoplasm of *Amoeba* is denser than the outside water and, thus, it has a relatively high osmotic pressure. Therefore, water enters the body through the plasma membrane by a process called **endosmosis**. Water is also taken in along with the food-particles. In the act of respiration also some water is formed in the body. If water goes on gathering in the body, the animal may burst. Therefore, the excess of water needs elimination to save *Amoeba* from bursting. This is brought about by the contractile vacuole.

The contractile vacuole appears as a small bubble near the hind end of the organism and is carried along by the streaming endoplasm to a place near the nucleus. Here it enlarges due to accumulation of water in it. When full, it shifts backwards to reoccupy its place of appearance. Now, it rises to the surface and on reaching the plasma membrane, it bursts due to contraction of surrounding cytoplasm and throws its water out. A new contractile vacuole is now formed at the place of the original one and the same process is repeated.

Formerly, it was held that the contractile vacuole also performed excretory function as the traces of urea and uric acid were found in the water thrown out by it. It is now recognized that the elimination of waste materials is only incidental to its real function of osmoregulation.

Irritability. *Amoeba* lacks nervous system and sense-organs, but it possesses irritability, which is the power of responding to external stimuli. This power enables it to protect itself from the unfavourable

environmental conditions. *Amoeba* responds to all sorts of stimuli, like contact, light, chemicals, temperature, electricity and humidity. A creeping *Amoeba*, when touched by a solid object, stops for a moment and then turns away from the obstacle to avoid it. A floating *Amoeba*, on the other hand, sticks to a solid object if it comes across in the way. *Amoeba* moves away from strong light, but prefers dim-lit areas. It also moves away from strong chemicals : acids, alkalies and salts. It shows normal activity at temperatures between 20°*C* to 25°*C*. Any decrease in the temperature slows down its activity. *Amoeba* contracts into a spherical mass if an electric current is passed through water in which it lives. When water dries up, *Amoeba* secretes a protective cyst around itself.

Encystment. Encystment occurs in *Amoeba proteus* on the approach of unfavourable conditions. In this process, it withdraws its pseudopodia and assumes a spherical form. Its protoplasm contracts by expelling outwater and secretes around it a thick chitinous protective covering called the **cyst-wall**. The structure, thus formed, is known as the **cyst**. Inside the cyst, *Amoeba* lies dormant, showing no sign of life. In this condition, it is not affected by drought, heat, cold, etc. The cysts, therefore, lie safe in the dry mud. On the return of favourable conditions, the cyst breaks and Amoeba starts active life.

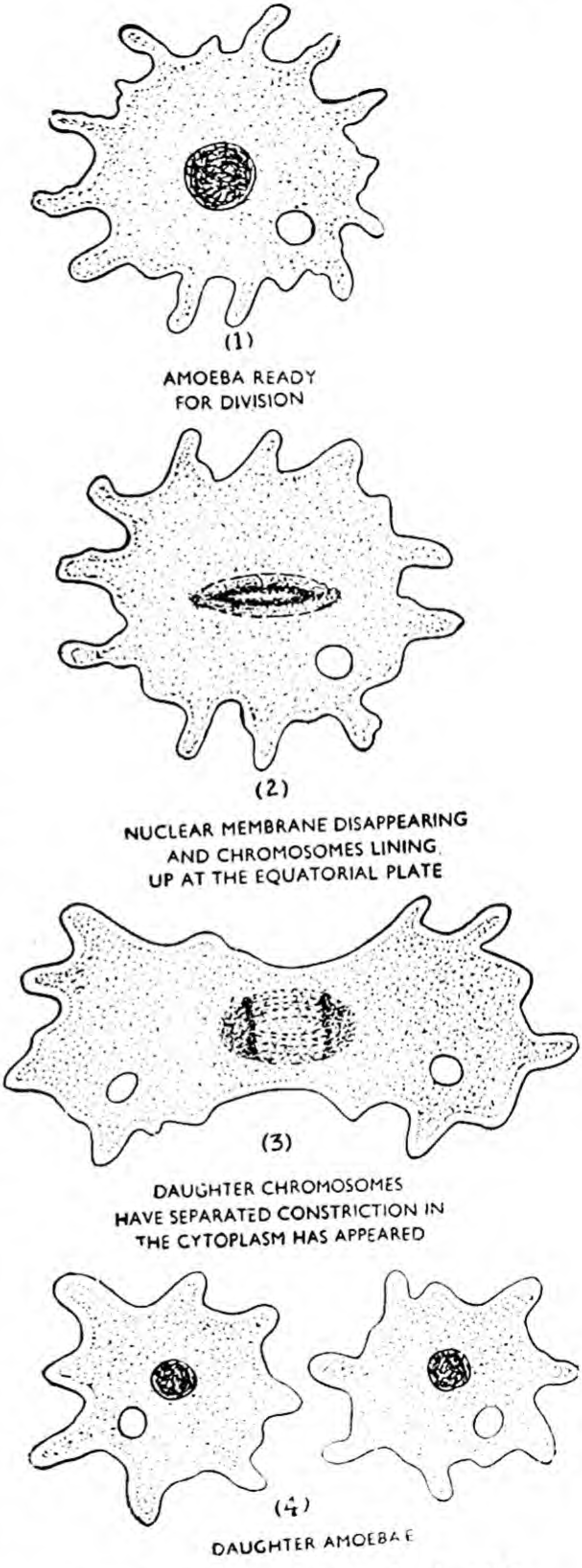


Fig. 6.5. Binary fission in *Amoeba*

From the dry mud, the cysts may be blown by the wind with the dust particles to new places of water. They may also be carried to new localities with the mud on the feet of various animals. On reaching water again, the cysts break to liberate the protected amoebae.

Encystment, thus, serves two functions. It enables *Amoeba* to tide over periods of drought (**perennation**) and also brings about its dispersal. It is from the cysts that amoebae are produced in the culture.

Reproduction. All the above mentioned vital activities occurring in the cytoplasm are controlled by the nucleus. When the cytoplasm has grown to its maximum size, any further growth will impair the controlling power of the nucleus by disturbing the nucleo-cytoplasmic ratio. Therefore, at this time, division or reproduction starts.

There is only asexual reproduction in *Amoeba*. It takes place in two ways : **binary fission** and **multiple fission**.

1. **Binary fission**. Binary fission is the division of the parent *Amoeba* into two daughter amoebae (Fig. 6.5). It occurs during favourable conditions and takes 33 minutes at 24°C. It begins when the animal has attained its normal size. For binary fission, *Amoeba* becomes more or less rounded, retaining short blunt pseudopodia. The nucleus divides into two nuclei by a modified mitosis. The two daughter-nuclei move away from each other. In the meantime, the body of *Amoeba* elongates and develops a constriction around its middle between the two nuclei. The constriction deepens and finally divides the body into two similar halves. This results in the formation of two daughter amoebae, each with one nucleus. The daughter amoebae feed and grow till the normal

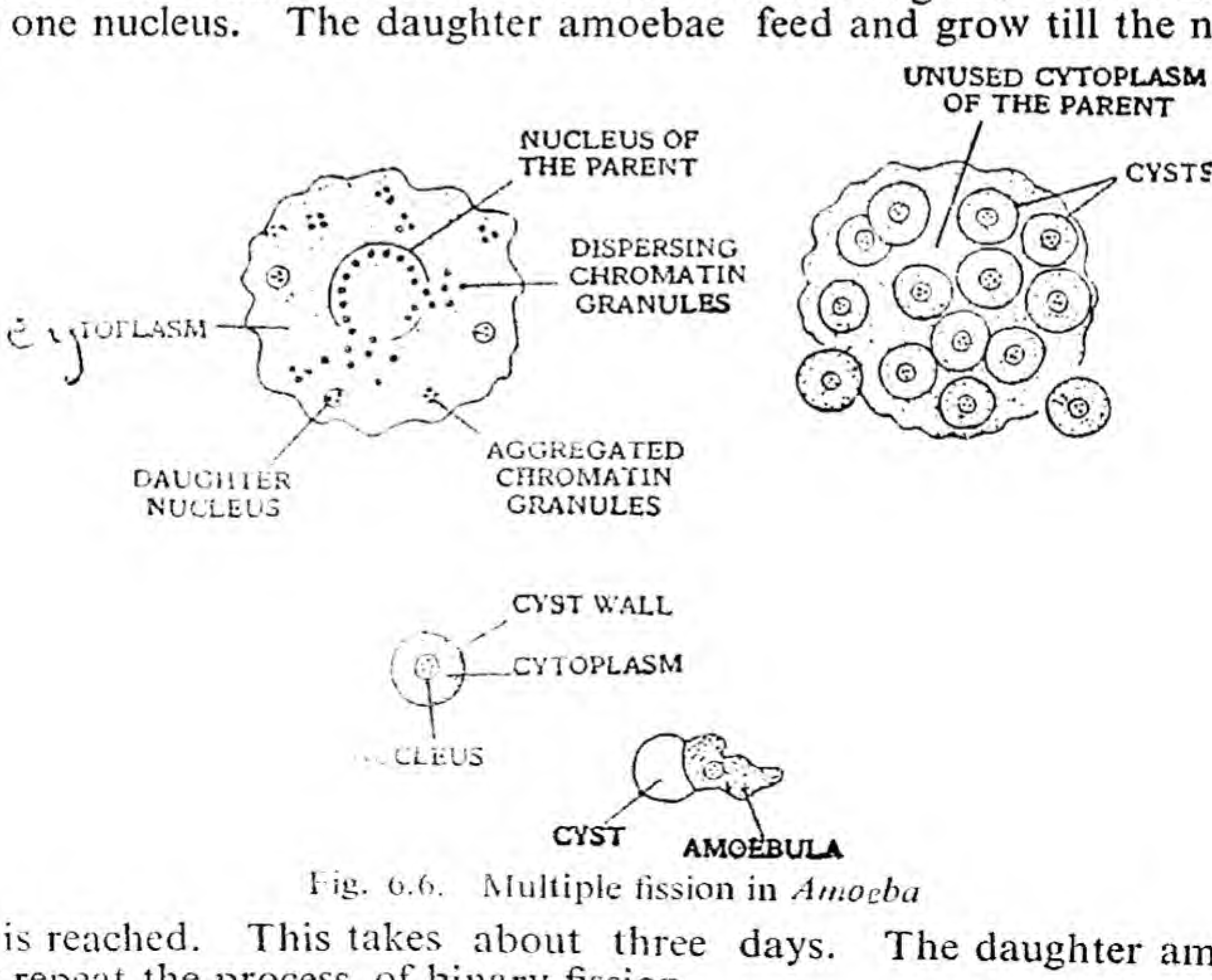


Fig. 6.6. Multiple fission in *Amoeba*

size is reached. This takes about three days. The daughter amoebae now repeat the process of binary fission.

2. **Multiple Fission**. Multiple fission is the division of a parent *Amoeba* into several daughter amoebae simultaneously. It usually occurs during unfavourable conditions like approaching desiccation, changing pH, etc. The chromosomes multiply by repeated division to produce numerous sets of chromosomes within the nuclear membrane. The nuclear membrane then disintegrates and the sets of chromosomes are set free in the cytoplasm (Fig. 6.6). Each set develops a nuclear membrane round itself and becomes a regular nucleus. Several nuclei are, thus, formed in the cytoplasm. A fragment of cytoplasm now gathers round each nucleus. Each nucleated mass of cytoplasm becomes surrounded by a tough resistant covering, the **cyst-wall**, and is called the **cyst**. In this way, several (about 200) cysts are formed within the parent body. A part of the cytoplasm of the parent remains unused in the formation of the cysts. The residual cytoplasm contains excretory crystals of the parent. It later on disintegrates to liberate the cysts. The cysts remain inactive or dormant during the unfavourable conditions. On the return of favourable conditions, each cyst hatches into a small *Amoeba*, which starts active life. This method of multiple fission is also called **sporulation** and the cysts formed, the **spores**.

Sporulation is known to occur during the favourable conditions also. Rather, it regularly occurs after a certain number of fissions. It not only brings about multiplication, but also enables the organism to survive during unfavourable conditions and to get rid of the excretory crystals.

Some amoebae undergo multiple fission inside the cyst (Fig. 6.7). In this process, the nucleus divides several times to produce a large number of nuclei, which come to lie near the periphery. A bit of cytoplasm gathers around each nucleus to form a daughter *Amoeba*. As many as 500—600 amoebae may be formed in one cyst. They are set free when the cyst breaks on the return of favourable conditions. The young amoebae possess pointed pseudopodia and are sometimes termed the **pseudopodiospores** or **amoebulae**. They lead an active life and ultimately grow into the adult animals.

Calkins has pointed out a sexual method of reproduction in *Amoeba proteus*, but his observations lack confirmation.

Immortality. *Amoeba* reproduces by binary fission. In this process, the parent *Amoeba* divides itself equally into two daughter amoebae. It does not retain with itself anything, which can afterwards die. Though the parent *Amoeba* loses its existence, it cannot be said to have died, as no dead body is found. In fact, the parent, after binary fission, starts living as two individuals. The latter grow in size and after undergoing another binary fission start living as four amoebae. The process continues indefinitely. Hence, *Amoeba* is **immortal**, *i.e.* it has no natural death. It may, however, die an accidental death in which it may be crushed or eaten up by large animals.

Regeneration. Power of developing the lost parts of the body is termed regeneration. It is well-marked in *Amoeba*. A part of *Amoeba*

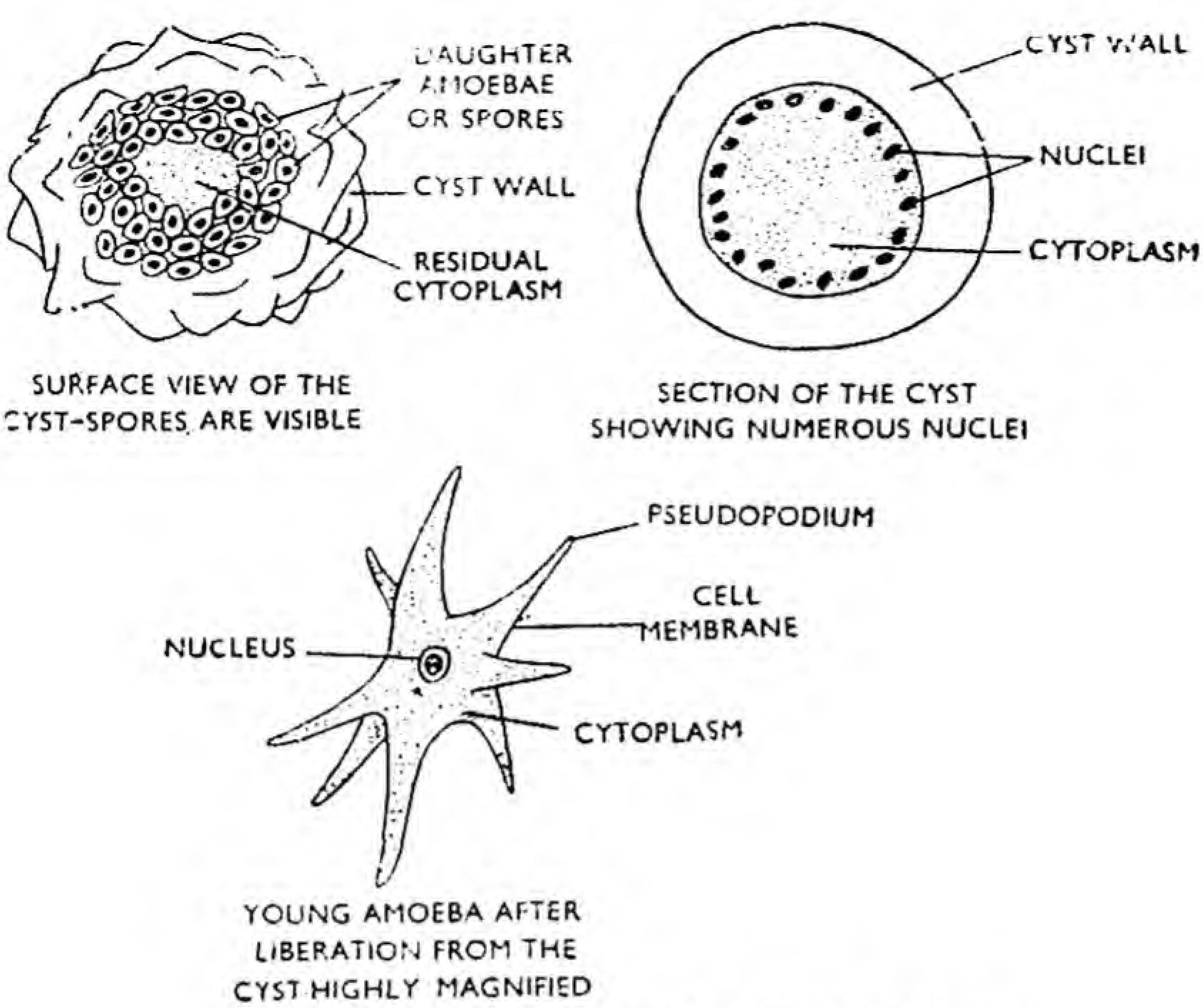


Fig. 6.7. Multiple fission inside a cyst

containing a nucleus functions normally and eventually grows into a complete organism. A part without nucleus, however, perishes. This suggests that the nucleus controls the life-activities of the body of *Amoeba*.

Adaptations to Environment

1. Minute size, light-grey colour against the background of mud, extremely slow movement and preference for dim-lit areas render *Amoeba* unnoticeable by its enemies. 2. Flattened form facilitates diffusion of oxygen into the body and of carbon dioxide and nitrogenous waste materials out of it. 3. The contractile vacuole provides it with a wonderful device for getting rid of water constantly diffusing into the body. 4. Omnivorous habit ensures adequate food everywhere. 5. High rate of binary fission maintains its population during favourable conditions. 6. Cyst-formation affords a good means of tiding over unfavourable conditions and dispersal to new localities.

Position in the Animal Kingdom

Amoeba is often regarded as the most primitive animal from which all other animals have evolved. This, however, does not seem to be true as the flagellates appear to be more primitive than amoebae.

Amoeba is also considered to be the simplest animal. Its simplicity is, however, limited to structure only. Physiologically, it is as complex as any other animal, because it carries on all the vital functions of life.

Classification

The proteus animalcule belongs to the

Phylum : **Protozoa**	Because of being acellular.
Sub-phylum : **Plasmodroma**	Because of having pseudopodia and lacking both nuclear dimorphism and conjugation.
Class : **Sarcodina** or **Rhizopoda**	Because of having pseudopodia.
Order : **Amoebida**	Because pseudopodia are blunt and do not anastomose.
Family : **Amoebidae**	Because of being naked.
Genus : *Amoeba*	Because of being free living and having a contractile vacuole.
Species : *proteus*	Because pseudopodia are often very long and sometimes branched and because there is a single nucleus with scattered chromatin.

TEST QUESTIONS

1. Give an account and mode of life of *Amoeba proteus.*
2. Comment on the statement. '*Amoeba* is immortal.' Can the same be said of any other organism ?
3. Make a labelled sketch showing the structure of *Amoeba.*
4. Describe the function of the following :—
   (*a*) Pseudopodia, (*b*) Contractile vacuole, (*c*) Cyst formation, (*d*) Food-vacuole.
5. What do you know about the habitat of *Amoeba* ? How can we prepare culture of this organism in the laboratory ?

CHAPTER 7

Plasmodium vivax

(The Malarial Parasite)

An organism, which obtains its food from another living organism is known as a **parasite**. The organism upon which a parasite feeds is termed the **host**. The organism, which causes malaria, is a parasite, hence malarial parasite.

Geographical Distribution

Plasmodium vivax is almost cosmopolitan in distribution. It occurs from 60°N to 40°S latitude. Its incidence is, however, much higher in the warmer parts of this region than in the colder parts.

Hosts

Plasmodium vivax has two hosts : man and mosquito. While it causes malaria in man, it is practically harmless to the mosquito. There must, of course, be some drain on the nutritive resources of the mosquito, but it seems to have developed tolerance to wastage of food.

Mosquito contains the sexual phase of the parasite and is regarded as the **primary** or **final host***, whereas man harbours the asexual phase and is termed the **secondary** or **intermadiate host**. Not all mosquitoes serve as the hosts of this parasite. It is only the female of the genus *Anopheles* which is the vector. It can be distinguished from the male by straight, unbranched and almost hair-like antennae. The male *Anopheles* has much branched antennae. *Anopheles* and the common house mosquito, called *Culex*, can be differentiated by their resting posture on a vertical surface. *Culex* keeps its body parallel to the surface, while *Anopheles* makes an angle with it. Moreover, *Anopheles* has spotted wings.

Life-cycle (Fig. 7.1)

The life-cycle of *Plasmodium vivax* may be sub-divided into three phases : a phase of growth and asexual multiplication occurring in man and called **schizogony** ; sexual phase or **gamogony** which starts in man and is completed in the mosquito ; and an asexual multiplicative phase termed **sporogony** in the mosquito.

1. Schizogony. Schizogony further consists of two phases : (*a*) the **exoerythrocytic** or **hepatic schizogony**, which occurs in the liver-cells

*In strict usage, the host which contains sexual phase of the parasite is called primary, the other secondary. Some authors, for purely medical reasons, regard man as the primary host.

of man and (*b*) **erythrocytic schizogony**, which takes place in the red blood-corpuscles or erythrocytes of man.

(*a*) **Exoerythrocytic Schizogony**. The parasites find their way into the blood of a healthy man along with the saliva of an infected female *Anopheles* mosquito, which bites for getting a blood-meal. At this stage, the parasites are called the **sporozoites**. Each sporozoite has a slender, slightly curved body tapering at either end. It is only 0·002 mm. long and contains a nucleus in the broad middle part. It is enclosed in a thin, firm and elastic cuticle, which imparts it a definite shape (Fig. 7.1). In about half an hour after their inoculation, the sporozoites leave the blood stream and get into the parenchymatous cells of the liver. Here they become spherical and are called the **cryptozoites**. Inside the liver-cell, the cryptozoite grows at the expense of its glycogen, fat and cytoplasm and forms a large rounded structure, the **schizont**. The latter undergoes multiple fission. In this process, the nucleus of the schizont divides into numerous nuclei, each ultimately gathering a bit of cytoplasm round itself. This results in the production of about 1,000 tiny parasites called the **cryptomerozoites** in a schizont. The rupture of the schizont and the liver-cell liberates the cryptomerozoites into the **liver-sinusoids**. The sinusoids are small blood channels with incomplete lining. From the sinusoids, the parasites enter fresh liver-cells to restart the exoerythrocytic schizogony.

When the cryptomerozoite has entered another cell of the liver, it is known as the **metacryptozoite**. It grows in size to form the **schizont**. The latter undergoes multiple fission and forms about 1,000 parasites called the **metacryptomerozoites**. The latter are of two types. Some are smaller and more numerous. They are called the **micrometacryptomerozoites**. Others are larger, but fewer. They are termed the **macrometacryptomerozoites**. Both types are released into the liver-sinusoids on the rupturing of the schizont and the infected liver-cell. The above described schizogonic cycles occur in the liver-cells **before** the parasites invade the red corpuscles of the host. Therefore, they constitute the **pre-erythrocytic phase** of the exoerythrocytic schizogony. It takes about 8—10 days. Thereafter, the parasites follow two lines of action. The smaller ones or micrometacryptomerozoites do not invade the liver-cells, but instead enter blood-stream and attack the red blood-corpuscles, thereby commencing the erythrocytic schizogony. The larger ones or macrometacryptomerozoites remain in the liver and invade the fresh liver-cells to start the **posterythrocytic phase** of the exoerythrocytic schizogony. The parasites formed in the posterythrocytic phase constitute a reservoir. They remain in the liver unaffected by medicine and natural immunity of the host. Whenever the immunity or resistance falls, the reserve parasites escape from the liver-cells into the blood-stream and attack the red blood-corpuscles, thus, causing relapse of malaria.

(*b*) **Erythrocytic Schizogony**. The erythrocytic schizogony starts when the parasites enter the red blood-corpuscles. Inside the corpuscle, the parasite assumes a rounded form and starts growing at the expense of the corpuscle. During the growth period, it is called the **trophozoite**.

The trophozoite develops in its body a large food-vacuole, which pushes the nucleus to one side. This gives the trophozoite the appearance of a signet-ring. This stage is called the **signet-ring stage**. With further growth, the vacuole disappears and the trophozoite assumes an irregular or amoeboid shape. The trophozoite is now in the **amoeboid stage**. With the help of its pseudopodia, the trophozoite ingests the

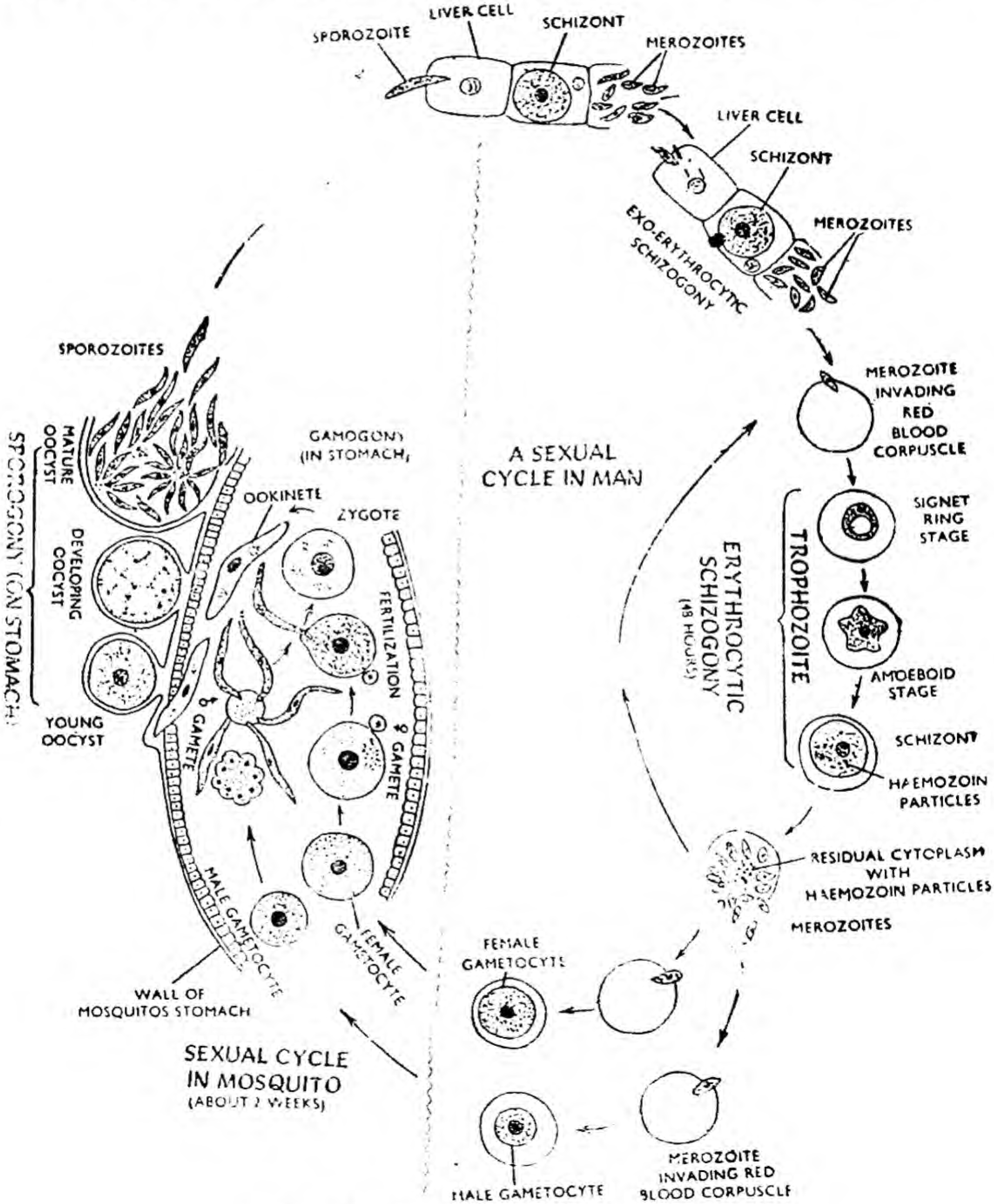


Fig. 7.1. Life-history of *Plasmodium vivax*

cytoplasm of the corpuscle. The cytoplasm of the corpuscle is digested and assimilated by the trophozoite. The haemoglobin is not digested. It gets decomposed into a yellowish-brown or black pigment, the **haemozoin** or **melanin**, which lies in the cytoplasm of the trophozoite. In about 36 hours, the trophozoite becomes mature. It, again, assumes a rounded form. It almost fills the corpuscle, which also gets enlarged in size. It is now ready for multiple fission and is called the **schizont**. Its nucleus divides to form 12 to 24 nuclei. The latter come to lie near the periphery, leaving the melanin in the centre. A bit of cytoplasm gathers round each daughter nucleus so that 12 to 24 tiny, uninucleate bodies are formed. These are called the **merozoites** or **schizozoites**. They are shorter and thicker than the sporozoites and are oval in shape. A portion of the cytoplasm of the schizont does not participate in the formation of merozoites. This residual cytoplasm contains the melanin and the metabolic wastes or toxins are produced by the parasite. The merozoites arrange themselves around the residual cytoplasm like the petals of a rose flower. This stage is called the **rosette stage**. About 48 hours after its infection, the weakened corpuscle ruptures and the merozoites are released into the plasma along with the residual cytoplasm, melanin and toxins. The residual cytoplasm and melanin are eaten up by phagocytes in the spleen, kidney and liver. Some merozoites are also destroyed by white blood-corpuscles, but many enter the fresh red corpuscles and repeat the erythrocytic schizogony to increase the number of parasites in the blood.

With the rupturing of the erythrocytes, the patient suffers an attack of malarial fever. In other words, an attack of malaria coincides with the completion of erythrocytic schizogony. In *Plasmodium vivax*, the erythrocytic schizogony takes 48 hours and, therefore, the fever recurs rhythmically every third day. The fever has been ascribed to the release of toxins from the merozoites. These toxins have not yet been experimentally demonstrated. The appearance of fever is due to the high metabolic activities of the patient in order to counteract the chilly effects produced by the destruction of the red corpuscles and the toxins released in the plasma with their destruction.

2. **Gamogony**. Every erythrocytic schizogony increases the number of parasites in the blood of the patient. After some time, they become so numerous that the host is likely to die due to large-scale destruction of red corpuscles. The death of the host indirectly means the death of the parasites also. The parasites may also be destroyed by the power of resistance developed in the host as a result of infection. In both the cases, the transmission of the parasites to a new host becomes essential for their safety. For this purpose, certain merozoites, after entering the red corpuscles, do not develop into schizonts. They, instead, develop into compact rounded bodies, which lack a vacuole and grow more slowly. These are the sexual forms and are called the **gametocytes** or **gamonts**. The gametocytes are of two types : **male** or **microgametocytes** and **female** or **macrogametocytes**. The microgametocytes are smaller and fewer ; their nucleus is relatively large and centrally placed ; and their cytoplasm stains faintly due to lack of reserve food. The macrogametocytes are

large and more numerous ; their nucleus is comparatively small and excentric ; and their cytoplasm stains deeply due to the abundance of reserve food. Both types of gametocytes have more melanin than the schizonts. The gametocytes are unable to develop further in the human blood. They die if not sucked up by the female *Anopheles* mosquito. They are also destroyed if sucked up by other types of mosquitoes. The mosquito sucks, along with the blood, not only the gametocytes, but also stages of erythrocytic schizogony. In the stomach of the female *Anopheles* mosquito, all the stages, except the gametocytes, are digested. The gametocytes, however, can withstand the action of digestive juices. They rupture the corpuscles and become free in the stomach of the mosquito.

The development of the gametocytes in the mosquito's stomach involves two important events : **gametogenesis** or gamete-formation and **fertilization** or fusion of male and female gametes.

(*a*) **Gametogenesis.** Each microgametocyte produces a few **male gametes or microgametes** by a sudden and explosive process, called **exflagellation** or **flagellation**. In this process, the nucleus of the microgametocyte divides to form 4 to 8 daughter nuclei; which migrate to the periphery. Then 4 to 8 long, slender threads of cytoplasm suddenly shoot out from the surface of the gametocyte. One daughter nucleus passes into each thread. This forms the male or microgametes. To begin with, the male gametes are attached to the unused cytoplasm of the gametocyte having melanin in it. Soon, however, they become free from the residual cytoplasm and start swimming by lashing movements in search of the female gametes.

The nucleus of the macrogametocyte cuts off one or two small fragments, which are excluded from the gametocyte with a bit of cytoplasm. The excluded structures probably correspond to the polar bodies. The macrogametocyte has now become a **female or macrogamete.**

(*b*) **Fertilization.** The female gamete develops a small projection, the **cone of reception**, on one side. One male gamete penetrates the female gamete through this cone. The **pronuclei** and cytoplasm of the two gametes completely fuse to produce a single cell, the **zygote**, with a fusion nucleus, the **synkaryon.**

The zygote, when formed, is rounded and motionless. It soon becomes elongated and worm-like and starts moving on the lining of the stomach. It is now called the **ookinete** or **vermicule**. The ookinete pierces through the wall of the stomach and comes to rest just beneath its outermost layer. Here it assumes spherical form and gets enclosed in thin, elastic, and pervious cyst-wall round it The cyst is derived partly from the zygote and partly from the insect tissues. At this stage, the parasite is called the **oocyst** or **sporont.** The oocysts look as rounded projections on the surface of the stomach (Fig. 7.2).

3. Sporogony. The oocyst now undergoes asexual reproduction called sporogony. It grows in size deriving nourishment from the mosquito through the pervious cyst-wall. The cyst-wall also enlarges to accommodate the growing parasite in it. The cytoplasm of the

oocyst develops a number of vacuoles and its nucleus divides repeatedly to form a very large number of daughter nuclei. Each daughter nucleus gets surrounded by a mass of cytoplasm. The resulting cells are called the sporozoites. Some cytoplasm of the oocyst is left unused in the formation of the sporozoites. There are about 10,000 sporozoites in an oocyst. They are arranged round the vacuoles.

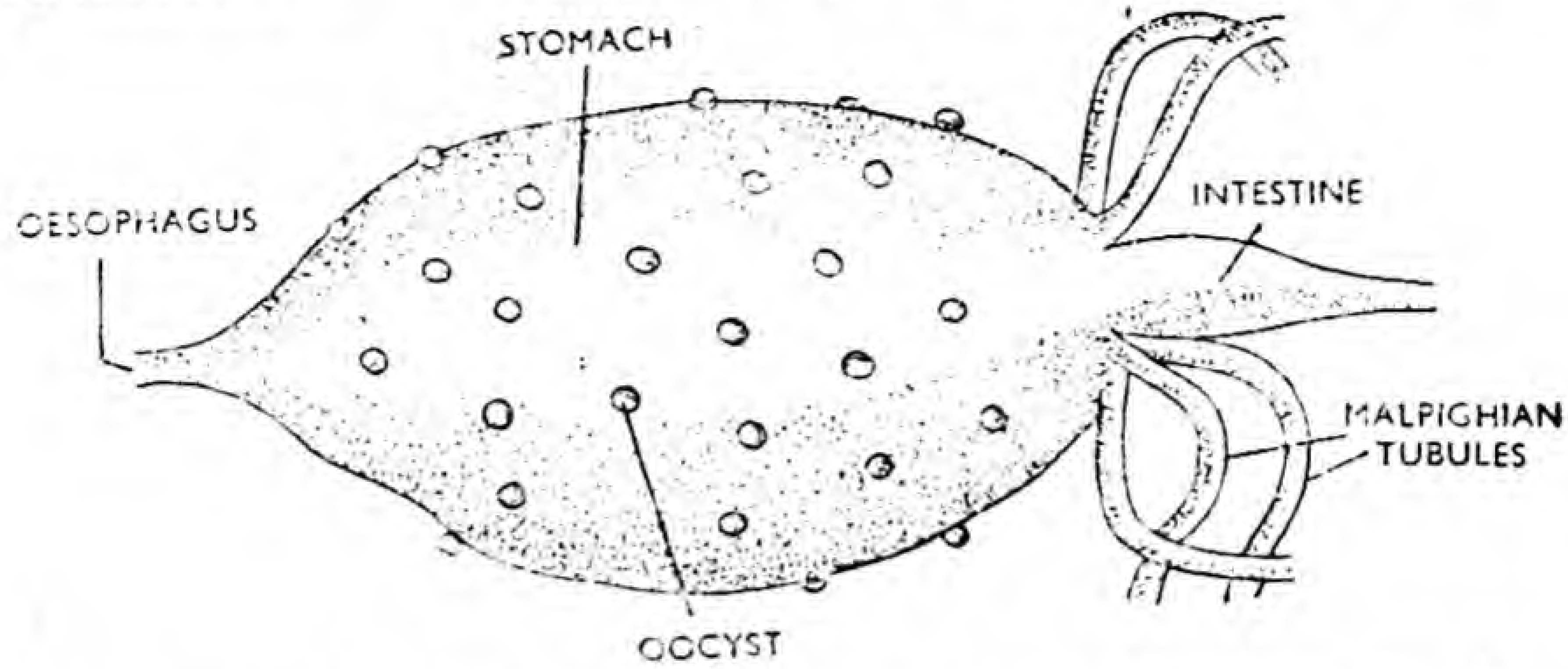


Fig. 7.2. Stomach of an infected mosquito showing encysted zygotes or oocysts

Soon, they break off from the residual cytoplasm of the oocyst. Ultimately, the oocyst ruptures and the sporozoites are set free in the haemocoel or body-cavity of the mosquito. In this haemocoel lie the salivary glands of the mosquito. From the body-cavity the sporozoites may enter any part of the body of the mosquito, but the majority migrate into the salivary glands and wait for their transmission into the blood of man with the mosquito-bite. A single infected mosquito harbours in its salivary glands as many as 200,000 sporozoites. One bite of such a mosquito may inject up to 1,000 sporozoites in man.

The entire development of the parasite inside the mosquito takes about 1 to 4 weeks.

Alternation of Generations

Sporogonic and schizogonic phases of the life-cycle of *Plasmodium vivax* may be said to constitute the **asexual generation** as in these phases parasite reproduces by an asexual method of multiple fission. Gamogony, on the other hand, represents the **sexual generation** as it involves the formation of male and female gametes and their subsequent fusion. These two generations follow each other in the life-cycle. This phenomenon is termed the **alternation of generations.**

Alternation of Hosts

Asexual and sexual generations of the life-cycle of *Plasmodium vivax* do not occur in the same host. The sexual generation begins in the human host and is completed in the mosquito, while the asexual generation starts in the mosquito and is continued in man. It, thus, follows that a change in the generation soon calls for a change of host. This regular change of host with a change in generation is called the **alternation of hosts.**

Species of Plasmodium

There are four species of *Plasmodium*, which cause different kinds of human malaria.

1. P. vivax. It causes benign tertian malaria, which attacks every third day, *i.e.* after 48 hours. The fever is mild and seldom fatal. This species is wide-spread in the tropical and temperate regions.

2. P. ovale. It also causes benign tertian malaria, which recurs every 48 hours. This is because it too completes its erythrocytic schizogony in 48 hours. This species is, however, rare and is found only in West Africa and South America.

3. P. malariae. It causes quartan malaria, which recurs every fourth day, *i.e.* after 72 hours. This is because it completes its erythrocytic schizogony in 72 hours. This species is found in both tropical and temperate regions, but it is not very common.

4. P. falciparum. It alone is capable of causing three types of malaria, viz. quotidian malaria, which attacks almost daily ; malignant tertian malaria, which recurs every 48 hours, but is very severe and often fatal ; and irregular malaria. This is because its erythrocytic schizogony takes 24 hours in some strains and 36—48 hours in others. This species is found only in the tropical regions.

Adaptations

Extremely small size of the body enables *Plasmodium* to live inside liver-cells and red blood-corpuscles. Very simple structure is correlated with its sheltered life within the bodies of the two hosts. It has dispensed with feeding and locomotory organelles because it finds enough food all round it and need not go about in search of it. It does not produce resistant cysts as it never comes in contact with the outside world. Excessive multiplication and reservoir of latent forms in the liver-cells ensure continuation of the race. Introduction in its life-history of a mosquito-host, which has a close relationship with man, provides a safe and sure means of transference from the infected to the healthy persons.

Malaria

Malaria has been for thousands of years a very serious disease of the tropical and temperate regions. Until recently, about 100 million people were infected in India alone and of these about a million died every year. Besides actual mortality, malaria also impaired the health of millions of people and reduced their resistance to infection of other diseases. Fortunately, it has now been brought under control.

Symptoms. The onset of malaria is preceded by yawning, lassitude, headache, muscular pain, etc. During the attack of malaria, the patient feels chilly and shivers, there is acute headache, and the body temperature rises up to 104°F. After a few hours, the body perspires freely and the temperature becomes normal. In chronic cases, there is general weakness and anaemia due to large-scale destruction of red blood-corpuscles. This is also accompanied by enlargement of spleen and liver.

Cause. Malaria is caused, as stated earlier, by the acellular organism, *Plasmodium* or the malarial parasite. The parasites, during their life-history in man, produce waste materials as a result of metabolic activities. These waste materials act as poisons or toxins in the human body and bring about malarial fever.

Transmission. Malaria fever or the malarial parasites are carried from the infected to the healthy persons by the female *Anopheles* mosquito. Only the female mosquitoes feed on the blood. The males suck plant sap. The mosquito sucks the parasites with the blood when it bites an infected person. In the mosquito's stomach, the parasites undergo sexual reproduction and sporogony. After this, they reach the salivary glands and the mosquito becomes ready to transmit infection to man. When this mosquito bites a healthy person, parasites are introduced into his blood along with the saliva, which the mosquito injects before sucking blood to prevent its clotting.

Types. There are several types of malaria, each caused by a different species of *Plasmodium*. The various species and the types of fever they cause, have already been described.

Incubation Period. The symptoms of malaria first appear about 10 days after the infection of the malarial parasites in man. This interval is known as the incubation period. During this period, the parasites multiply so that they become sufficiently numerous to produce malaria.

History. Malaria was previously known by a variety of names like ague, marsh fever, intermittent and remittent fever, jungle fever, etc. The name "malaria" is a combination of two Italian words and literally means "bad air" (*mala*=bad : *aria*=air). This name was given by *Macculoch* in 1827 on the belief that it was caused by the foul air of the marshy localities. It was in 1880 that *Laveran*, a French army medical officer, for the first time, discovered the malarial parasites in the blood of a malarial patient. The entry of the parasites in human blood continued to be a mystery for a long time. In 1892, a German doctor *Richard Pfeiffer* suggested the role of some blood-sucking insect in the transmission of malaria. In 1894, a Scottish Physician, *Sir Patrick Manson*, suggested the role of mosquitoes in malaria transmission. Working on this suggestion, *Sir Ronald Ross* of the Indian Medical Service, succeeded in establishing the "mosquito-malaria relationship". He found oocysts of *Plasmodium* on the stomach of the female *Anopheles* mosquito previously fed on the blood of a malarial patient. This discovery was made on August 29, 1897, ever since called the "Mosquito Day". A year later, *i e.* in 1898 Grassi and his fellows worked out the entire life-history of the human malarial parasites in the *Anopheles* mosquito. For a long time, it was believed that the parasites entered the red blood-corpuscles as soon as introduced into the blood by the mosquito. *Shortt* (1948) and *Garnham* (1954) discovered the pre-erythrocytic schizogony in the liver-cells.

Control. Knowledge of the life-history of the malarial parasites has made it possible to devise measures to control this disease. The measures fall under the following two categories :

I. Offensive Measures. Since two different organisms, namely, the mosquitoes and malarial parasites, are involved in malaria, the offensive measures are required to be taken against both of them. These measures are of a different nature and will be described separately.

(*a*) Offensive Measures Against Mosquitoes. Mosquitoes can be destroyed by the following methods :—

1. Drain off or fill up all ditches, ponds and pools with earth so that the mosquitoes may not find water to breed in.

2. If the above places are too large to be drained off or filled up, sprinkle kerosene oil or solution of D.D.T. on water so that the mosquito larvae and pupae may not breathe fresh air and may die of suffocation.

3. If the water of the above places is to be used for drinking or other domestic purposes, add larvicidal fishes (Sticklebacks, Minnows, Trouts, etc.), ducks, dragon-fly naiads, and insectivorous plants (*Utricularia*), as these will eat up the mosquito larvae.

4. Spray suitable insecticides like D.D.T. in and around the human habitations to kill the adult mosquitoes. The latter can also be killed or driven out of the houses by fumigation with sulphur. The adult mosquitoes can also be avoided by removing unnecessary vegetation from and around the houses.

(*b*) Offensive Measures Against Parasites of Malaria. The malarial parasites can be killed by taking suitable medicines. Originally, quinine, derived from the bark of a Peruvian tree, was used. Later, synthetic drugs like paludrine, atabrine, etc. were employed. These days chloroquine phosphate, which destroys the erythrocytic forms, is used in combination with primaquine, which kills the exoerythrocytic forms in the liver. Still more promising is daraprim. It is slow in action but, in due course of time, it kills the parasites both in the blood and liver and also in the mosquito that feeds on the person.

II. Defensive Measures. The defensive measures include the precautions by which we protect ourselves from mosquitoes without killing them. These measures are fairly simple but very effective in the control of malaria. These are summarised below :—

1. Keep hands and feet covered in the evening.

2. Apply some insect-repellent (mosquito oil or cream) to the exposed parts of the body at night so that the mosquitoes do not bite.

3. Sleep under mosquito-nets to avoid mosquito bites.

4. Screen all habitations from mosquitoes with wire-gauze over doors, windows and ventilators.

Classification

The malarial parasite comes under the

Phylum :	**Protozoa**	Because of being acellular.
Sub-Phylum :	**Plasmodroma**	Because sexual reproduction involves fusion of gametes and locomotory organs and nuclear dimorphism are lacking.
Class :	**Sporozoa**	Because of spore-formation from the zygote.
Order :	**Haemosporidia**	Because of having amoeboid trophozoite living in the red corpuscles.
Family :	**Plasmodidae**	Because schizogony occurs in red corpuscles and produces haemozoin.
Genus :	*Plasmodium*	True malarial parasites.
Species :	*vivax*	Because schizogony takes 48 hours, haemozoin is light brown, and fever caused is benign tertian.

TEST QUESTIONS

1. Define alternation of generations. Explain this phenomenon with reference to the life-history of the malarial parasite.

2. What is a parasite ? Name the parasite that causes malaria in human beings. How is this fever transmitted from one person to another ? What factors are responsible for the spread of malaria in an epidemic form ? Suggest measures to control malaria.

3. Describe the sexual method of reproduction in *Plasmodium*.

4. Describe the following terms :—
Parasite, Host, Primary host, Secondary host, Infected animal, Incubation period, Schizogony, Alternation of hosts.

5. Give an account of the part of the life-history of *Plasmodium* spent in man.

6. Illustrate the life-history of *Plasmodium* with a series of labelled figures only.

7. Name the mosquito which spreads malaria and show how this can be distinguished from the other mosquito. What stages comprise the life-history of the mosquito and which of them concern us in malaria ? What would be the result if all the malarial mosquitoes were destroyed.

8. Give a brief history of malaria.

CHAPTER 8

Paramecium caudatum

(The Slipper Animalcule)

Not all Protozoa have the apparent simplicity of *Amoeba* and *Plasmodium*. Some forms show quite a high degree of differentiation within a single unit of protoplasm and *Paramecium* is one of them. This organism was among the first living things seen with the newly-invented microscope in the 17th century.

There are several species of *Paramecium*, which differ from each other in minor details. Of these, *Paramecium caudatum* is studied as a type of the ciliates since it is plentiful all over the world, has a comparatively large size convenient for microscopic examination, and its structure and reproduction have been thoroughly worked out.

Culture of *Paramecium caudatum* is prepared in the same way as that of *Amoeba proteus*.

Habitat

Paramecium caudatum occurs in fresh water all over the world. It is specially plentiful in ponds, pools, streams, rivers, reservoirs, lakes and aquaria, where decaying vegetable matter and bacteria abound. This is because the bacteria form its chief food. It is interesting to note that active specimens of this species have been observed from the moist soil around Moscow.

Habits

Paramecium caudatum is a free-living organism. It actively swims about in water but can creep on solid surface also. Occasionally it becomes stationary, getting attached to a fragment of vegetation. It is omnivorous in diet and reproduces in a variety of ways, which are both asexual and sexual,

Morphology

Size, Colour and Shape. *Paramecium caudatum* is a microscopic animal and measures 0·15 to 0·3 mm. in length and 0·045 to 0·075 mm. in breadth. It appears to the naked eye as a minute whitish or slightly-greyish speck when the test-tube containing it is examined against light. Under the microscope it seems to be almost colourless and transparent. Unlike *Amoeba*, *Paramecium* has a definite shape, which resembles the sole of a slipper, hence the slipper animalcule. The name "*Paramecium*", given by John Hill in 1752, also suggests the shape of the animal (Gr. paramekes=oblong). The body is somewhat cylindrical, rounded in front and pointed behind. The maximum width of the body is a little behind the middle.

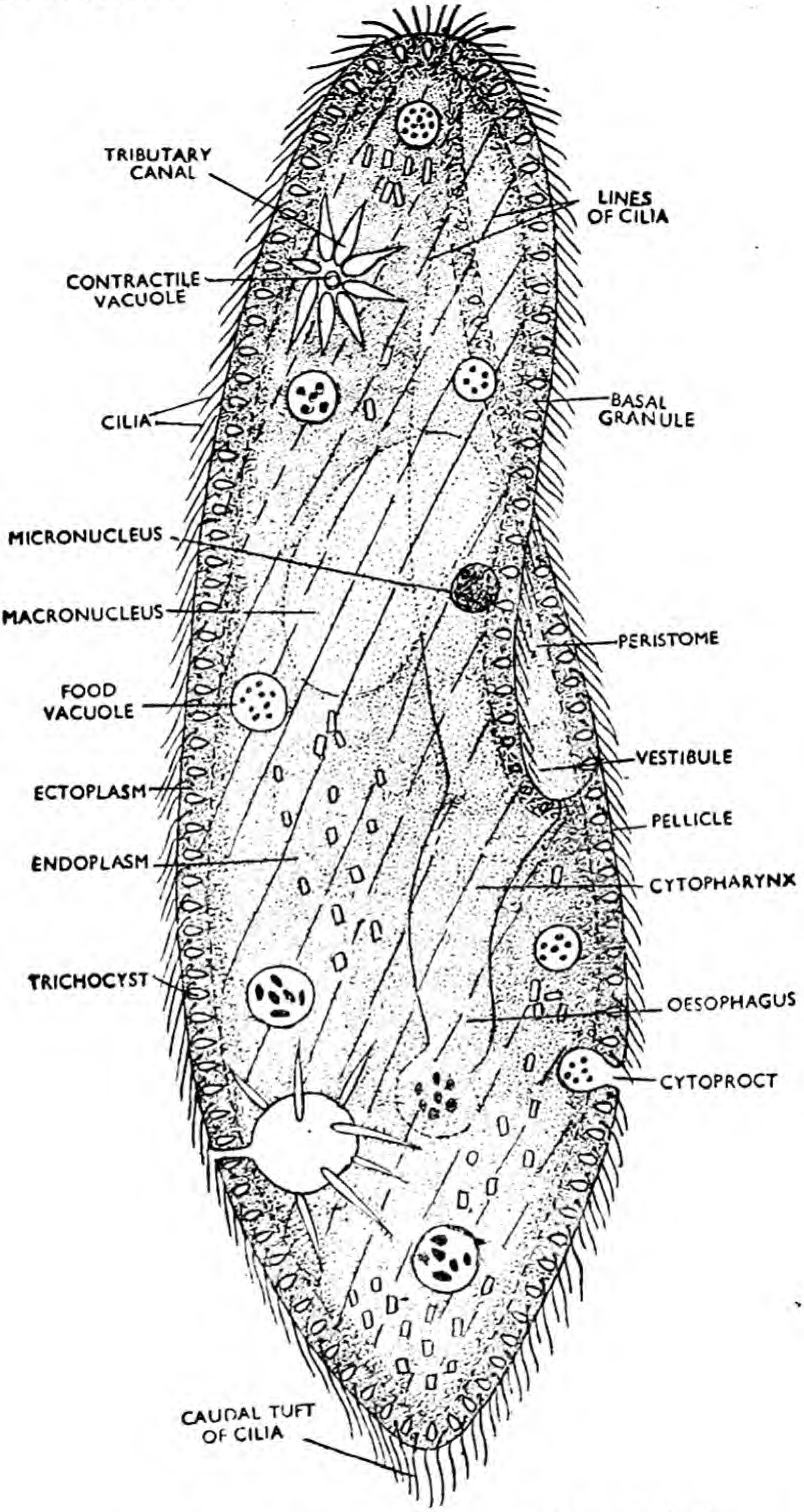


Fig. 8.1. *Paramecium caudatum* (Lateral view)

Pellicle. The body of *Paramecium caudatum* (Fig. 8.1) is enclosed by a thin, firm, 2-layered membrane, the **pellicle**. It maintains the shape of the animal and also serves as a skeletal structure. It is, however,

elastic and enables the animal to bend or squeeze through narrow passages. The pellicle, when seen under greater magnification, shows a hexagonal pattern of ridges surrounding shallow depressions (Fig. 8.2). The centre of each depression has a pore through which a fine process, the **cilium**, projects out. The ridges bear apertures for discharging the underlying **trichocysts.**

Food-Passage. On ventral side of the body there is a shallow depression, the **oral groove** or **peristome.** It starts from the left side of the anterior end and extends obliquely backwards towards the right side to the region a little behind the middle of the body. It is widest at the anterior end. Its posterior part is funnel-like and is called the **vestibule.** The latter ends in a small oval aperture, the **mouth** or **cytostome.** The cytostome leads into a tube, **cytopharynx,** which extends upwards through the cytoplasm for a short distance and then turns backwards as a relatively narrow tube termed the **oesophagus.** The oesophagus ends in the endoplasm and often has at its end a food-vacuole in the process of formation. The oral groove makes the animal asymmetrical. Shortly behind the oesophagus, on the ventral side, there is a pore in the pellicle for the elimination of faecal matter. It is visible only during the act of egestion and is called the **anus** or **cytopyge** or **cytoproct.**

Cilia. The entire body is covered with fine processes, the **cilia.** They are arranged in longitudinal, but slightly oblique rows. The cilia are of uniform size all over the body except at the hind end where they are slightly longer and form the **caudal tuft.** The cilia of the caudal tuft are sensory in nature and act as a tactile organelle. The cilia are present in the food-passage also. The arrangement of cilia in the pharynx and oesophagus is rather complicated. They are closely set, but do not fuse to form an undulating membrane as held earlier. The cilia arise from the small **basal granules** or **kinetosomes** lying beneath the pellicle. The adjacent basal granules are connected by longitudinal and transverse fibrils termed the **interciliary fibrils** or **neuronemes** (Fig. 8.2). All the interciliary fibrils originate from a small darkly staining granule, the **motorium** or **control centre,** situated in the dorsal wall of the cytopharynx. The motorium, interciliary fibrils and basal granules serve to co-ordinate the movements of the cilia and are said to form the **neuromotor system.** This neuromotor system of *Paramecium* favourably corresponds to the nervous system of higher animals.

A cilium consists of an axial filament, the **axoneme,** embedded in an elastic protoplasmic **sheath,** which is continuous with the outer layer of the pellicle (Fig. 8.3). The axial filament is itself formed of eleven fibrils that extend its full length and fuse with the basal granule within the pellicle. Nine of these fibrils are double and occur in a ring round the remaining two that are single and lie at the centre.

The cilia help the animal in locomotion and capturing food.

Cytoplasm. The cytoplasm, as in *Amoeba,* is differentiated into two regions : the **ectoplasm** or **cortex** and the **endoplasm** or **medulla.** There is, however, no apparent line of demarcation between the two regions.

The ectoplasm forms a thin, clear and relatively firm outer layer. The basal granules, interciliary fibrils and trichocysts lie in the ecto-

plasm. It also contains fine contractile strands, the **myonemes, running** in longitudinal direction. They enable *Paramecium* to bend and squeeze its body through narrow passages by their differential contraction.

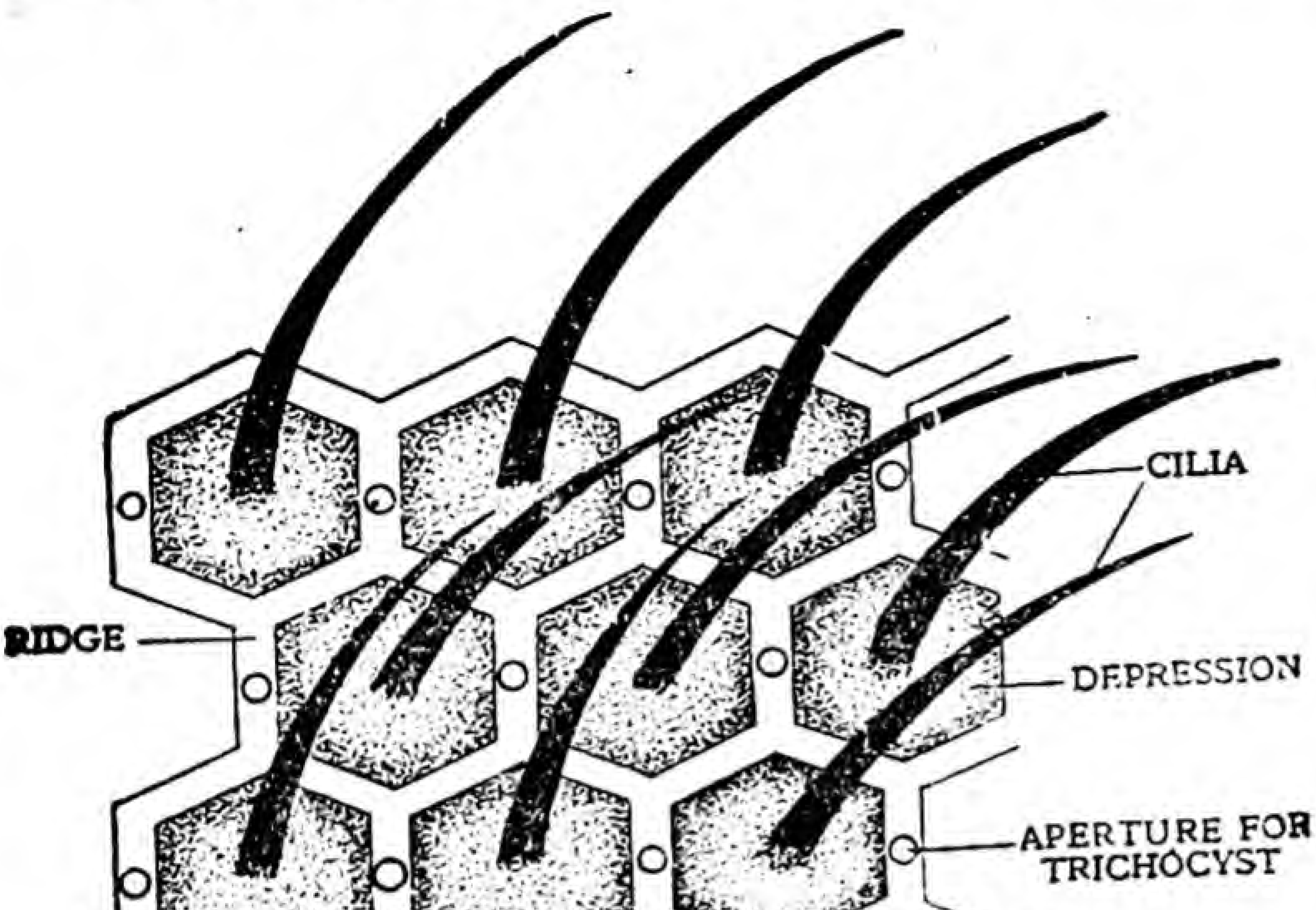


Fig. 8.2. A part of the pellicle (highly magnified)

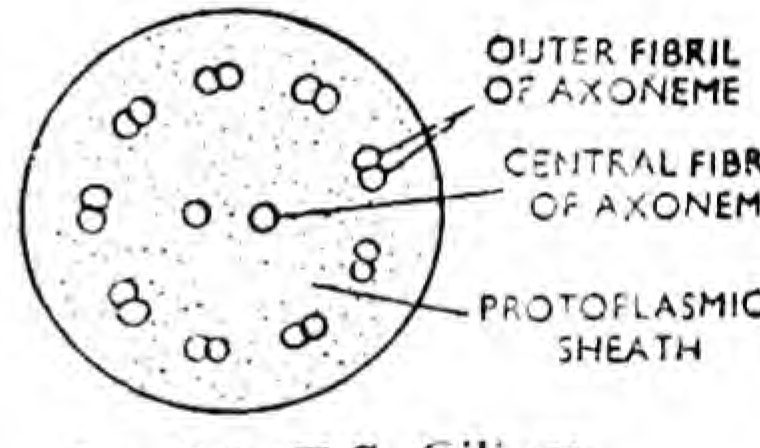


Fig. 8.3. T.S. Cilium

The endoplasm is granular and more fluid central mass. It forms the bulk of the animal. It contains the **nuclear apparatus, contractile vacuoles, food-vacuoles**, reserve food-materials like glycogen and lipids and crystals of various shapes.

Nuclear Apparatus. The nuclear apparatus is situated in the middle of the body above the gullet. It comprises two nuclei, which differ from each other not only in appearance (size and shape), but also in function. The phenomenon is called **nuclear dimorphism.** One nucleus is larger and bean-shaped. It is known as the **macro-** or **meganucleus.** It is also called the **vegetative nucleus** as it controls the vegetative activities of the animal. The other is smaller and rounded. It is called the **micro-nucleus** or **generative nucleus.** It controls the process of reproduction. It is lodged in a depressien of the macronucleus.

Contractile Vacuoles. There are two large contractile vocuoles in *Paramecium.* They lie in the innermost part of the ectoplasm of the dorsal surface. The anterior vacuole is one quarter of the distance from the anterior end and the posterior vacuole the same distance from the hind end. There is a minute **pore** in the pellicle directly above each vacuole (Fig. 8.9). A fine **tubule** connects each vacuole with its pore.

Each vacuole is surrounded by 6—10 pear-shaped radiating canals known as the **feeding** or **tributary canals.** These canals run parallel to the surface, but extend slighty into the endoplasm. A feeding canal consists of 3 parts : **injector**, **ampulla** and **terminal part.** The injector lies adjacent to the vacuole (Fig. 8.4). The contractile vacuoles serve to regulate the water contents of the body.

Food-vacuoles. The food vacuoles vary in size and number. They are almost spherical and contain ingested food-particles and water. They are bounded by a thin membrane and circulate in the endoplasm. The food-vacuoles serve as temporary stomachs as food is digested in them.

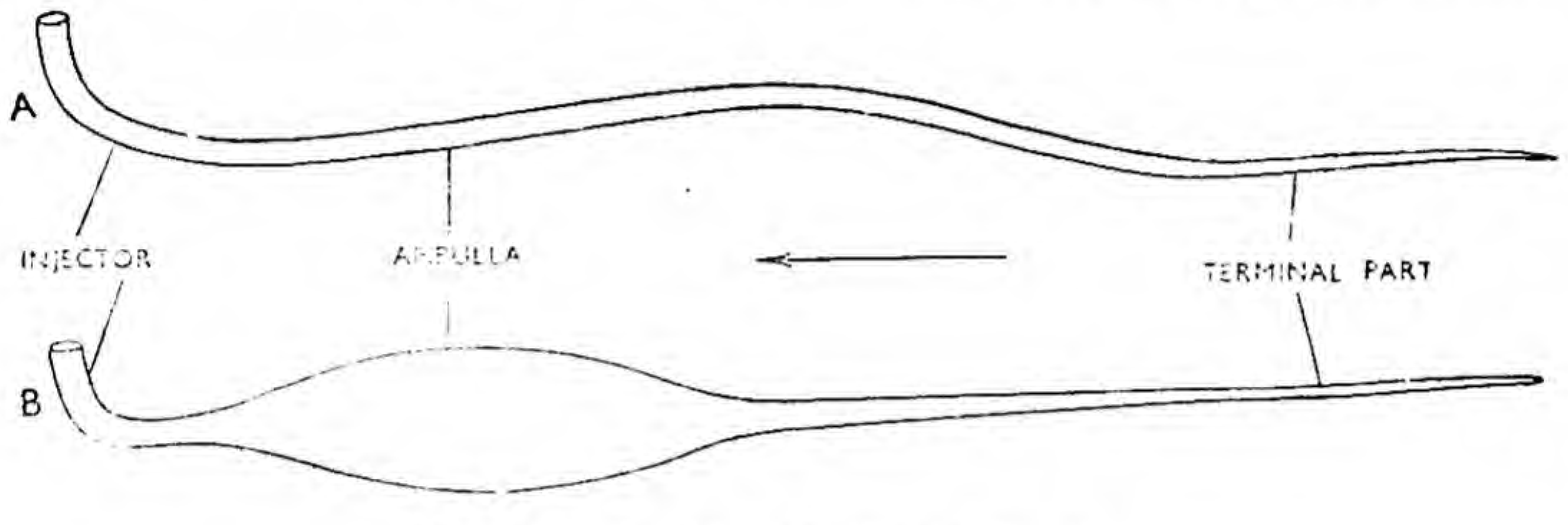


Fig. 8.4. A—Empty tributary canal
B—Full tributary canal

Physiology

The various physiological processes occur in a more organized manner in *Paramecium* than in *Amoeba*. This is correlated with greater morphological differentiation in the former than in the latter.

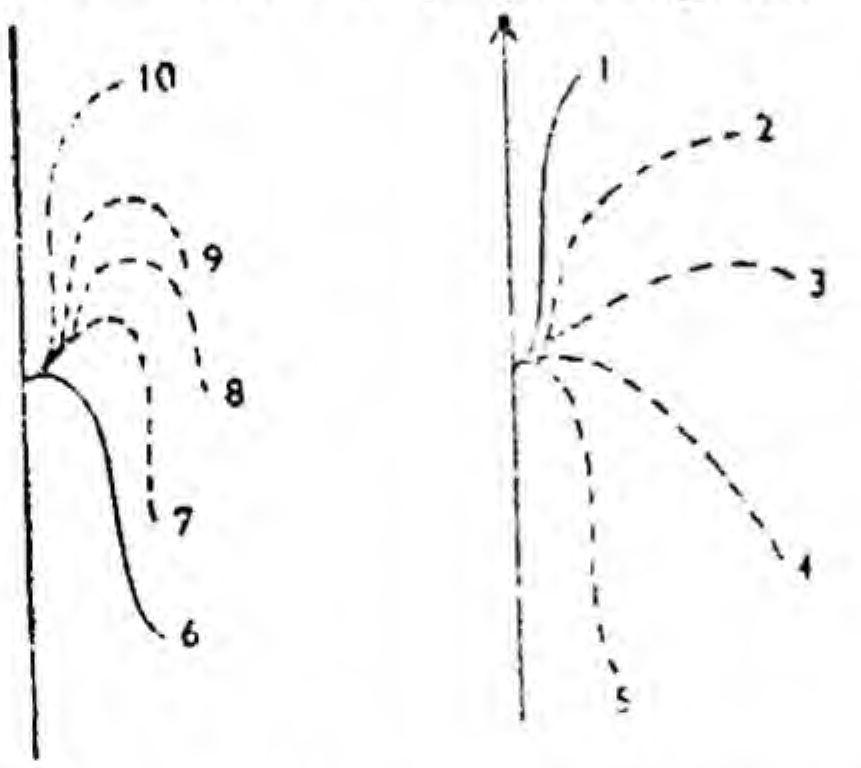


Fig. 8.5. Effective (Right) and recovery (Left) stroke of a cilium

Locomotion. *Paramecium* swims actively in water by rhythmic beating of cilia. A ciliary beat consists of 2 phases : an **effective stroke** and a **recovery stroke.** During the effective stroke, the cilium stiffens and moves almost as a straight rigid rod to become parallel to the body surface. During the recovery stroke, the cilium becomes limp and returns to its original vertical position in a greatly flexed condition, thereby exposing less surface to the resistance of water (Fig. 8.5). The

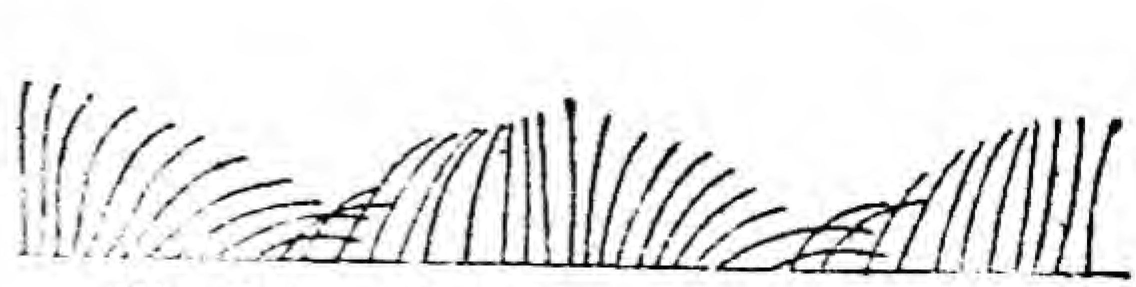


Fig. 8.6. Metachronous movement of a row of cilia

effective stroke of the cilium is caused by the contraction in one plane of its axial filament and the recovery stroke by the elasticity of the

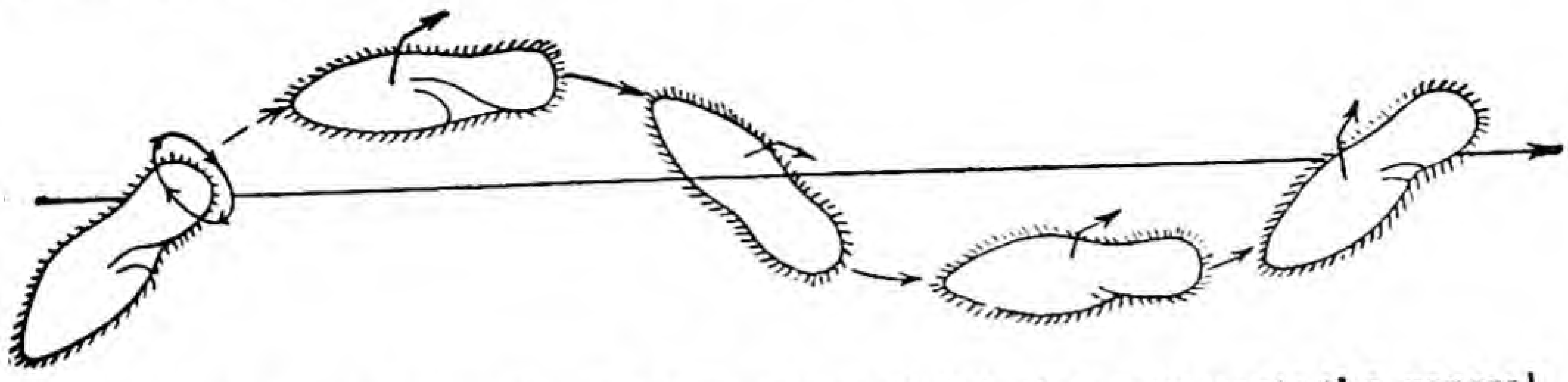


Fig. 8.7. Locomotion in *Paramecium*. Solid line represents the general direction ; the dotted line (spiral) shows the path followed by the organism. A circle round the anterior end in the first figure and arrows on the subsequent figures show the direction of rotation

protoplasmic sheath. It is the effective stroke of the cilium which, by acting against the resistance of water, gives push to the body. The cilia neither move one by one nor all at the same time. Instead, they move in metachronous waves, much like the lashing of tall wheat in the strong wind (Fig. 8.6). For normal progression, the cilia beat backward and the animal is pushed forward in the same way as the backward strokes of the oars carry the boat ahead through water. Cilia do not beat straight backward. Instead, they beat obliquely to the right, thereby causing the animal to roll over to the left. As a result of this, the organism, while swimming forwards, rotates on its long axis in the manner of a left spiral. (Fig. 8.7).

The effective strokes of the cilia lining the oral groove are more powerful than those of the body cilia. This makes the anterior end of the body swerve (turn) continually away from the oral side. Since the body is rotating on its long axis, swerving occurs alternately to all sides. In the beginning, the oral side is downwards and the body bends upwards ; a little later (due to axial rotation) the oral side comes to face the right and the body turns to the left ; still later the oral side gets directed upwards and the body swings downwards ; finally the oral side shifts to the left and the body swerves to the right. The same process is repeated over and over again. As the swerving in one direction is compensated by an equal swerving in the opposite direction, the organism progresses along a spiral path round a straight axis. The spiral is anticlockwise when seen from behind.

The spiral locomotion of *Paramecium*, thus, results from three factors : forward push, axial rotation and swerving of the anterior end to the aboral side.

Paramecium can also swim backwards. During backward swimming, the cilia beat forward and all the processes are reversed.

Paramecium swims at the rate of one millimetre per second. Its speed, however, appears to be much faster under the microscope. This is because the microscope magnifies the speed as much as it magnifies the object.

Paramecium can also glide or creep with cilia over a solid substratum.

Nutrition. As compared with *Amoeba, Paramecium* has a well marked digestive system comprising the oral groove or peristome, vestibule, cytostome, pharynx, oesophagus, food-vacuoles, and anus or cytopyge. Except the food-vacuoles, all the organelles are permanent structures.

(*a*) **Food.** *Paramecium* is holozoic, taking solid organic food. Its food consists of bacteria, diatoms, small protozoons, tiny fragments of larger animals and plants. It is, thus, omnivorous in diet. It moves from place to place in search of food. It prefers carbohydrate and protein materials and avoids fats except in conditions of food shortage.

(*b*) **Ingestion.** Food is captured with the help of cilia. Constant vibrations of the cilia lining the oral groove drive a current of water towards the mouth. The current of water sweeps the food-particles towards the mouth through which they are passed into the pharynx. Here the cilia push them into the oesophagus. The cilia of the oesophagus exert a circumvolutional effect on the food-particles and bring about their aggregation into small rounded masses. A few cilia arranged crosswise at the base of the oesophagus act as a strainer to check the passage of large food particles. The spheres of food formed in the oesophagus are pushed towards the endoplasm. Finally, they collect in a droplet of water at the end of the oesophagus. The droplet of water with its food-particles is called the **food vacuole.** It is pinched off from the oesophagus by a constriction of the surrounding cytoplasm.

(*c*) **Digestion.** After their separation from the oesophagus, the food-vacuoles circulate through the endoplasm along a definite path, which is functionally equivalent to a digestive tract (Fig. 8.5). After separating from the oesophagus, the food-vacuoles first go round the oesophagus once and then describe the major part of a figure of '8'. This circulation of the food-vacuoles is brought about by the rotary streaming movements of the fluid endoplasm known as **cyclosis.** The endoplasm secretes enzymes, which pass into the food-vacuoles and gradually digest the food. The contents of the food vacuoles show first an acidic and then an alkaline reaction as in *Amoeba.*

The enzymes acting on the food include the **amylase,** which converts starches into sugars ; **proteinase,** which breaks the proteins into peptides

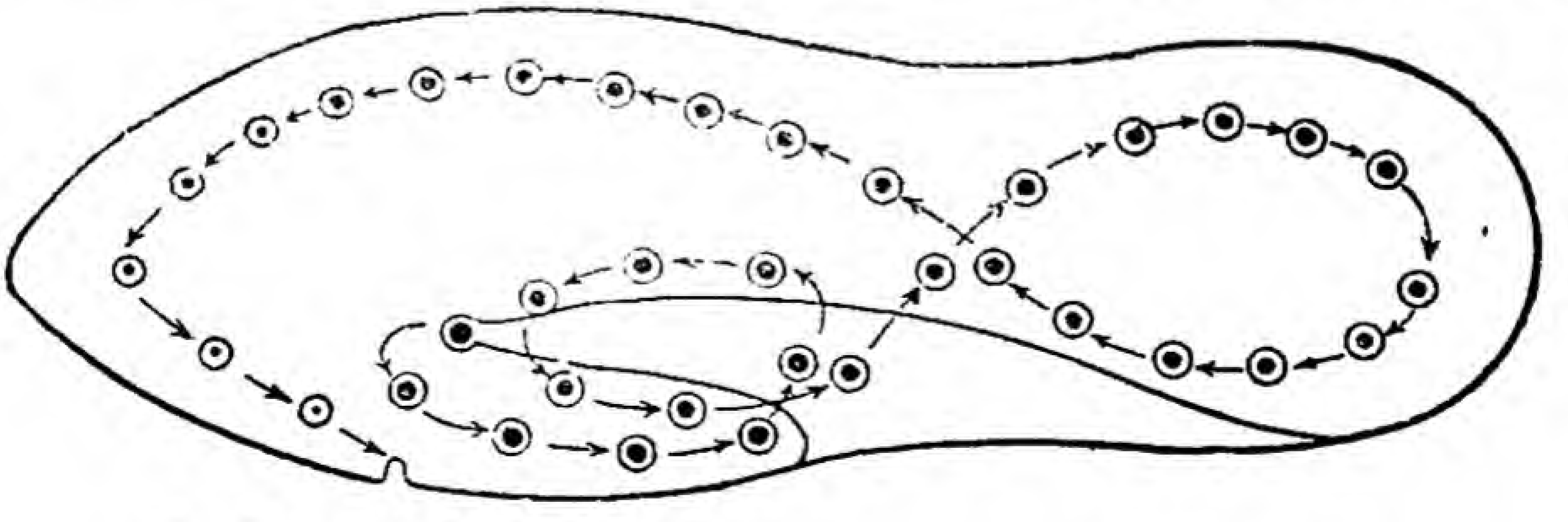


Fig. 8.8. Cyclosis of the food-vacuoles in *Paramecium*

during the acid phase of the food-vacuole and **dipeptidase** that changes the peptides into amino-acids during the alkaline phase. The digestion of fat is controversial in *Paramecium*. Some hold that the lipids found in the endoplasm are formed from the glycogen. Others hold that fats are digested by an enzyme called **lipase** during alkaline phase of digestion.

(*d*) **Absorption**. The soluble foods resulting from digestion pass through the membrane of the food-vacuoles into the surrounding cytoplasm. This is called the absorption of food. As digestion and absorption progress, the food-vacuoles decrease in size till only indigestible matter is left in them. Cyclosis of the food-vacuoles ensures equal distribution of food to all parts of the body.

(*e*) **Assimilation**. The food absorbed into cytoplasm may be synthesised into protoplasm or some of it may be coverted into storage products like glycogen and lipids. All this occurs under the influence of enzymes.

(*f*) **Egestion**. The food-vacuoles containing indigestible residue or faeces are eliminated through the anus.

Respiration. Respiration in *Paramecium* occurs through the general surface of the body as in *Amoeba*. Water contains some oxygen dissolved in it. This oxygen comes partly from the air and partly from the aquatic plants. The partial pressure of the dissolved oxygen is more than that in the body of *Paramecium*. Therefore, oxygen from water passes into the organism through the pellicle by diffusion. In the cytoplasm there occurs oxidation of food materials, particularly the carbohydrates, under the influence of some enzymes. This results in the production of water and carbon dioxide and release of energy, which is utilized by *Paramecium* in movements and metabolism. The carbon dioxide formed in the body has a greater partial pressure than that in the outside water. Therefore, it diffuses out of the body through the pellicle.

Excretion. Excretion is concerned with the elimination of nitrogenous waste matter from the body. In *Paramecium* this material is urea. Its removal occurs by diffusion through the general body surface.

Osmoregulation. There are two **contractile vacuoles** for osmoregulation in *Paramecium* as compared with *Amoeba*, which has only one. Osmoregulation is, therefore, more efficient in the former than in the

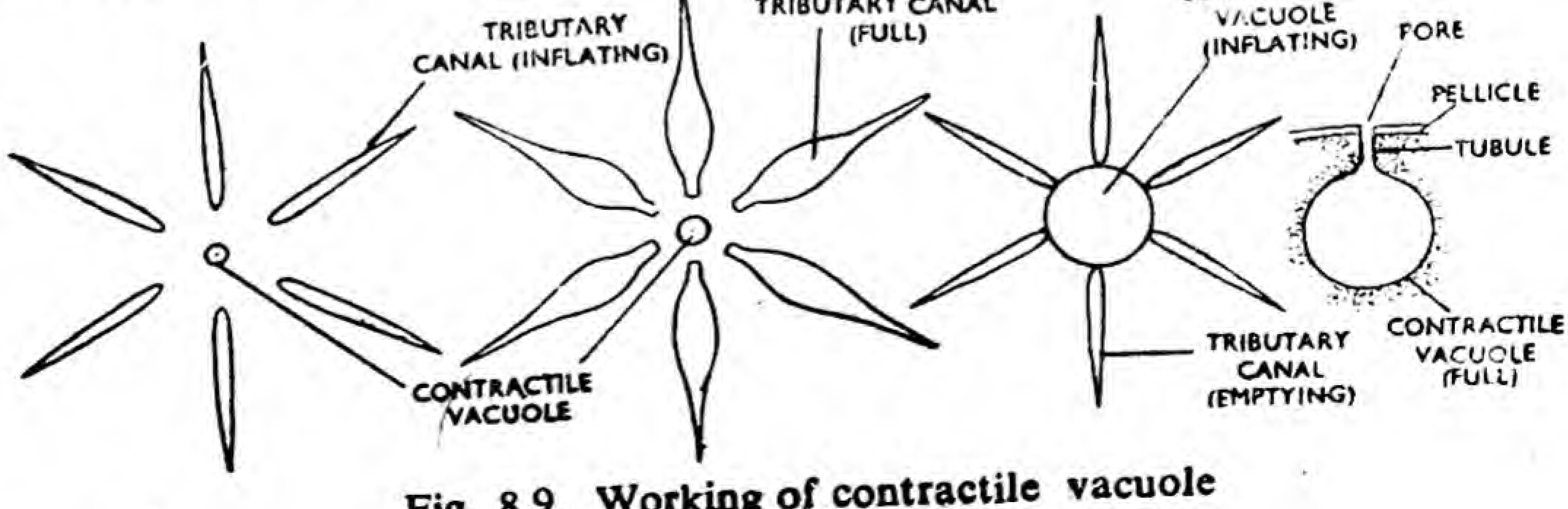


Fig. 8.9. Working of contractile vacuole

latter. The surplus water from the cytoplasm collects first in the feeding canals, which consequently swell up from mere streaks (Fig. 8.9). When the feeding canals are full of water, their inner ends or injectors emit minute water droplets that unite to form a contractile vacuole. The latter gradually expands as it receives more water droplets from the feeding canals, which shrink correspondingly. When full, the contractile vacuole contracts and throws its water to the exterior through a minute tubule. which connects the vacuole with the pore in the pellicle on the dorsal surface. The pore opens at the time of discharge, getting closed by a membrane soon after it. When the vacuole is fully distended **(diastole)**, the feeding canals disappear for a while and reappear as small streaks soon after the contraction **(systole)** of the vacuole. The canals again swell up by collecting water and the whole process is repeated.

* (The two contractile vacuoles do not work alternately as reported earlier. The posterior vacuole works more quickly than the anterior one, probably because the presence of the pharynx and oesophagus provides more surface for **endosmosis.**)

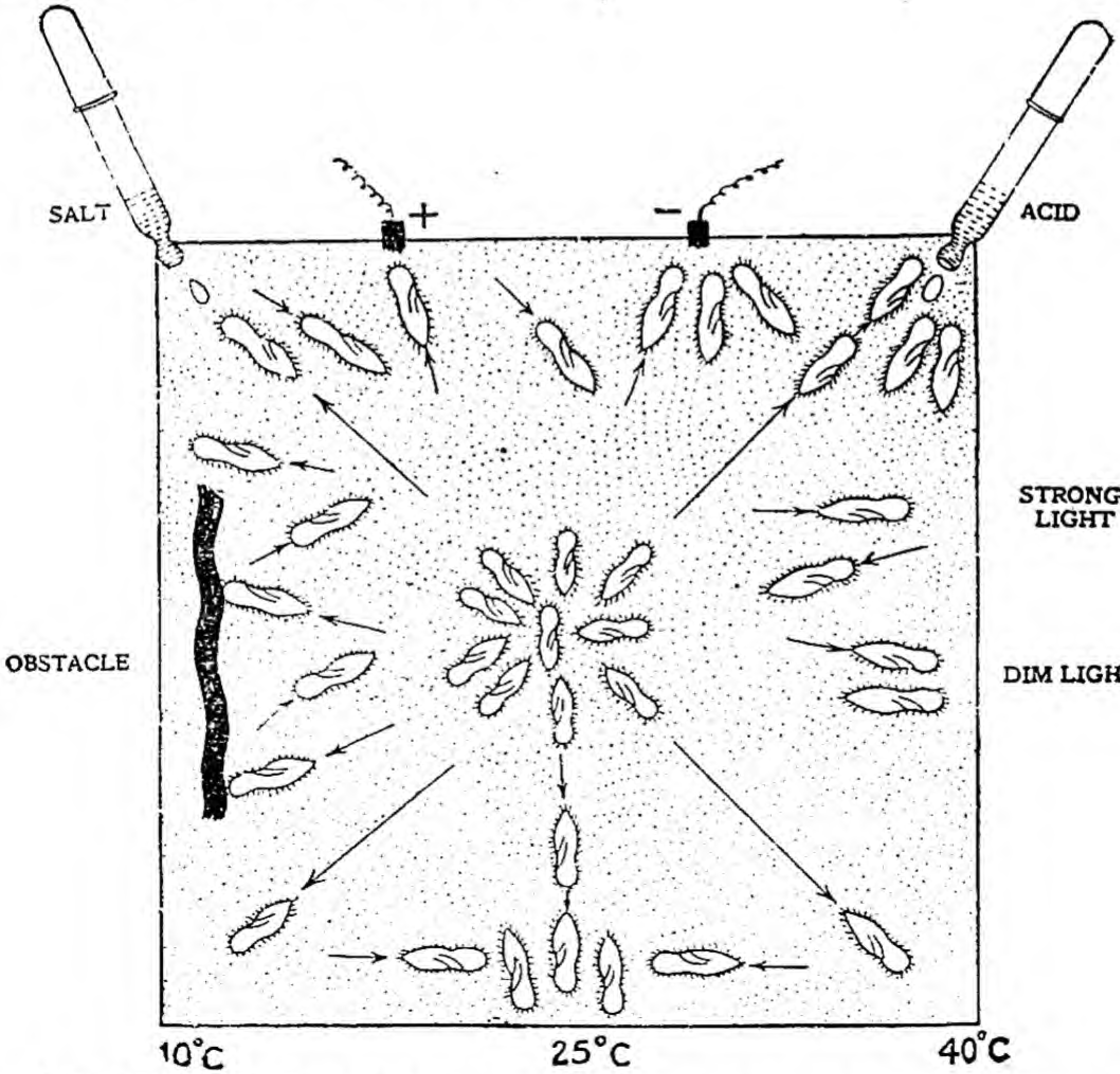


Fig. 8.10. Behaviour of *Paramecium* to various conditions of environment

It has been estimated that *Paramecium* expels out its own volume of water every half-hour.

Sensitivity. *Paramecium* has no sense organs except the caudal tuft of tactile cilia. Yet, it responds to all sorts of external stimuli like chemicals, light, temperature, contact, electric current, etc. On encountering a change in the medium, it stops for a moment and takes water in the buccal groove to test it. If found satisfactory, it resumes swimming, otherwise changes the direction. This action is repeated till it finds a favourable medium. It shows a positive response for a weakly-acidic environment (Fig. 8.10). This is advantageous to it as a slightly acidic medium contains more bacteria, which form an important source of its food. *Paramecium* swims away from salt solutions. It prefers moderate light and temperature around 25°*C*. On coming in contact with a solid object, it stops for a while, reverses its movement and then goes ahead in a new direction. This is repeated till a clear path is found. This is called **avoiding reaction** or negative response. In an electric field, *Paramecium* moves towards the negative pole.

Defence and Anchorage. The trichocysts are often considered to be the organs of defence and anchorage in *Paramecium*. They are small fusiform bodies situated in the ectoplasm with their long axes perpendicular to the surface of the body (Fig. 8.11). Each trichocyst is a sac containing an absorptive substance and closed by a cap. When stimulated by contact or chemicals, the ectoplasm suddenly contracts. This pushes the cap of the trichocyst aside and water enters it. The absorptive substance swells up and elongates into a long needle-like filament (Fig. 8.12), which shoots out through a pore in the pellicle. Small enemies of *Paramecium* are likely to be confounded by sudden explosion of trichocysts. The tips of the filaments discharged by the trichocysts are sticky and *Paramecium* uses them for attachment at a place having greater concentration of bacteria so that it may feed on them conveniently.

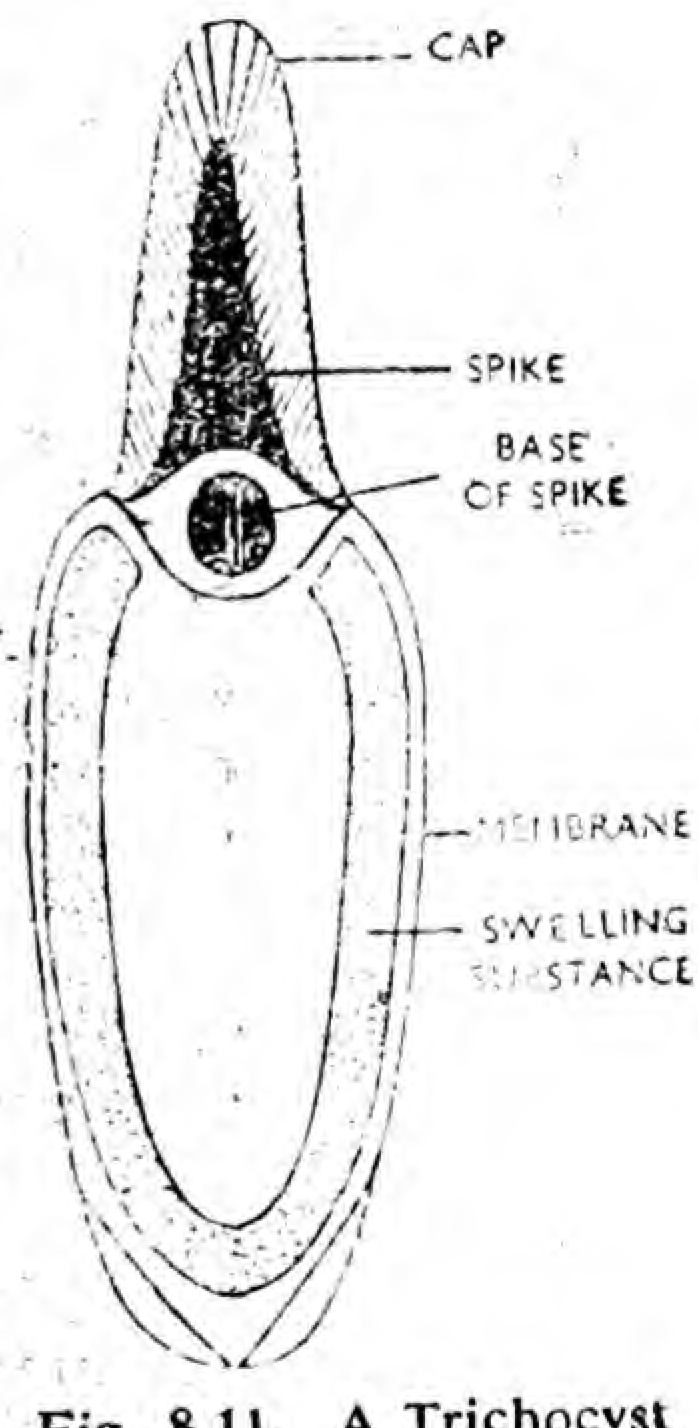


Fig. 8.11. A Trichocyst

The exploded trichocysts are broken off the body, when *Paramecium* moves away and are replaced by new ones.

Dispersal. *Paramecium* abundantly occurs in fresh-water ponds subject to periodic drying. This indicates that it has some mechanism for protection against desiccation. This mechanism is supposed to be the formation of resistant cysts. The fact that culture of *Paramecium* can be made by soaking organic matter in water also suggests that the formation of cysts occurs in this protozoon. The cysts resemble sand grains.* The cysts not only protect the organism from

*Michelson (1928) succeeded in obtaining cysts of *Paramecium* under extraordinary conditions.

unfavourable conditions, but a bring about its dispersal.

Reproduction. *Paramecium* shows asexual as well as sexual reproduction. The asexual reproduction occurs by binary fission. The sexual reproduction usually takes place by conjugation, but at times by processes called **autogamy, cytogamy, hemixis** and **endomixis.**

1. Binary Fission (Fig. 8.13). Binary fission is the commonest type of reproduction in *Paramecium*. In this process, a full grown individual divides transversely into two daughter individuals. Before the beginning of fission, *Paramecium* stops feeding, develops two minute pores near the middle of its body for the contractile vacuoles that are to appear later for the daughter individuals and doubles its cilia. During binary fission, *Paramecium* becomes less active and assumes a somewhat spindle-like form. Its oral groove disappears. The micronucleus divides by mitosis and the two micronuclei formed move away from each other. The mitosis is of typical protozoan type in that the nuclear membrane persists. The chromosomes that appear in mitosis are very small, numerous and compactly arranged. Consequently, it has not been possible to determine their number. The macronucleus divides by amitosis, in which it simply elongates and constricts transversely near the middle into two. A transverse constriction now appears around the body between the daughter nuclei. In the meantime, a new cytopharynx and cytostome are formed for the future posterior daughter *Paramecium* by budding from the original cytopharynx and cytostome, which remain in the future anterior daughter *Paramecium*. Each daughter individual receives one contractile vacuole from the parent and develops one new contractile vacuole. The anterior daughter retains the anterior parental vacuole as its posterior vacuole and develops a new one anteriorly. The posterior daughter retains the posterior parental vacuole as its posterior vacuole and develops a new one anteriorly. This means that the ends where the daughters separate become their anterior ends. The constriction round the parent body gradually deepens and finally results in the separation of the daughter paramecia. Each daughter develops the oral groove and starts growing into an adult.

Fig. 8.12. An exploded trichocyst

The newly formed daughter paramecia neither resemble each other nor the typical vegetative parent so that for a while they can be distinguished as the anterior daughter (called the **proter**) and the posterior daughter (termed the **opsthe**). Soon, however, they assume the typical form.

The whole process of binary fission is completed in about two hours and it may occur two or three times a day in favourable con-

ditions. This produces a huge number of paramecia in a short period. It is estimated that a single *Paramecium* may produce as many as 280 million descendents in one month.

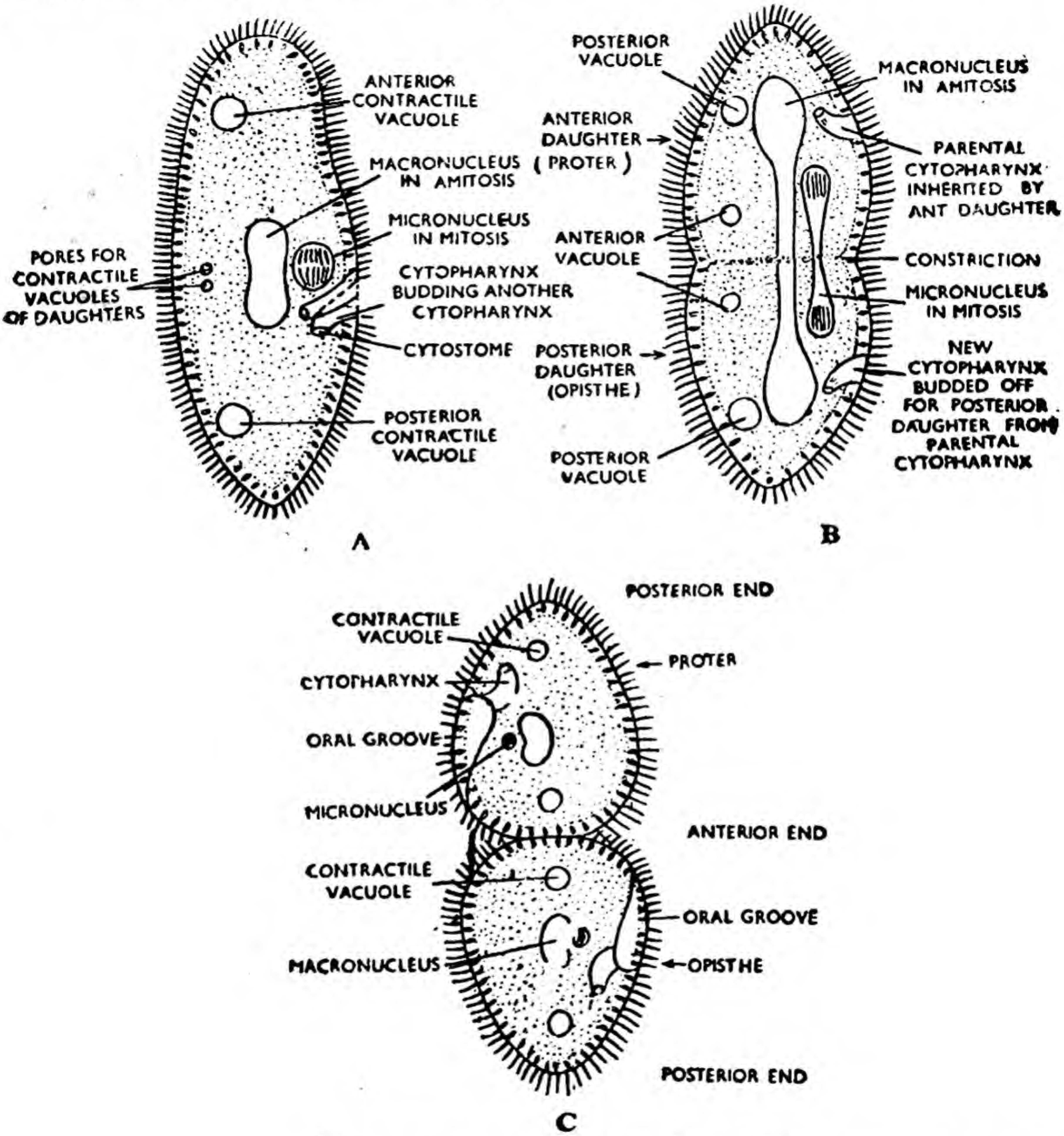


Fig. 8.13. Binary Fission in *Paramecium*.

2. Conjugation. Conjugation is an elaborate process and is well known for *Paramecium caudatum*.

(*a*) Definition. Conjugation is a process of reconstruction of nuclei involving the fusion of gametic nuclei or pronuclei of two different individuals, which pair temporarily for this purpose.

(*b*) **Procedure.** There are 13 varieties in *Paramecium caudatum*, each variety having two mating types. Conjugation is possible only between two individuals of **different mating types** of the **same variety.** This differentiation into mating types is only physiological and not morphological.

Conjugation takes place at night or early in the morning. Two paramecia of different mating types of the same variety adhere to each other by their ventral or oral surfaces. Their endoplasms become continuous by degeneration of the pellicle and ectoplasm in the region of the pharynx. This intimate connection may be compared with coition in higher animals. Paramecia, in this paired condition, are known as the **conjugants.** They continue swimming, but suspend feeding.

The macronucleus, being only vegetative in function, does not take any part in conjugation. It simply breaks up into small pieces, which are absorbed by the cytoplasm (Fig. 8.14). The micronucleus, being generative in function, exhibits a good deal of activity in conjugation. In each conjugant, it grows larger and undergoes two successive divisions, the first of which is reductional and the other equational. This produces four haploid micronuclei in each conjugant. Of these four newly-formed micronuclei, three disappear and each conjugant is left with a single micronucleus. The three degenerating micronuclei correspond to the polar bodies formed in the maturation of the metazoan ovum. The surviving micronucleus now divides equationally to produce two slightly unequal micronuclei in each conjugant : the smaller active **male** or **migratory pronucleus** and the larger passive **female** or **stationary pronucleus.** This makes paramecia **hermaphrodite.** The male pronucleus of each conjugant migrates into the other individual and fuses with its female pronucleus. Each conjugant now possesses a diploid fusion nucleus, the **zygote nucleus** or **synkaryon.** This fusion of the nuclear material from two individuals is known as **amphimixis** and corresponds to the cross fertilization of higher animals. The two conjugants now separate and are called the **exconjugants.**

In each exconjugant (Fig. 8.14), the zygote nucleus divides three times successively by mitosis, producing eight nuclei. Of these eight nuclei, four become enlarged and form the macronuclei, while the other four remain small and form the micronuclei. Three micronuclei disappear. Each exconjugant now has four macronuclei and one micronucleus. The micronucleus divides mitotically into two micronuclei. The exconjugant now divides transversely into two in such a way that each individual formed receives two macronuclei and one micronucleus. The micronucleus of each individual again divides mitotically to produce two micronuclei. The individual again splits transversely into two, each receiving one macronucleus and one micronucleus. Thus, from each exconjugant four young paramecia are produced.

(*c*) **Significance.** Conjugation has two-fold significance : **genetic** and **physiological,** for *Paramecium.*

(*i*) Physiological significance lies in the rejuvenation, *i.e.* restoration of vitality, of paramecia. This, however, is not always true.

Conjugation may produce weak and abnormal organisms also. This is because the nuclear exchange that occurs in conjugation brings about new genetic make-up, which is as likely to result in a weak stock as in a good one. It is, thus, not the mere development of a new meganucleus, but its chromosomal set-up that determines whether the organism will be strong or weak.

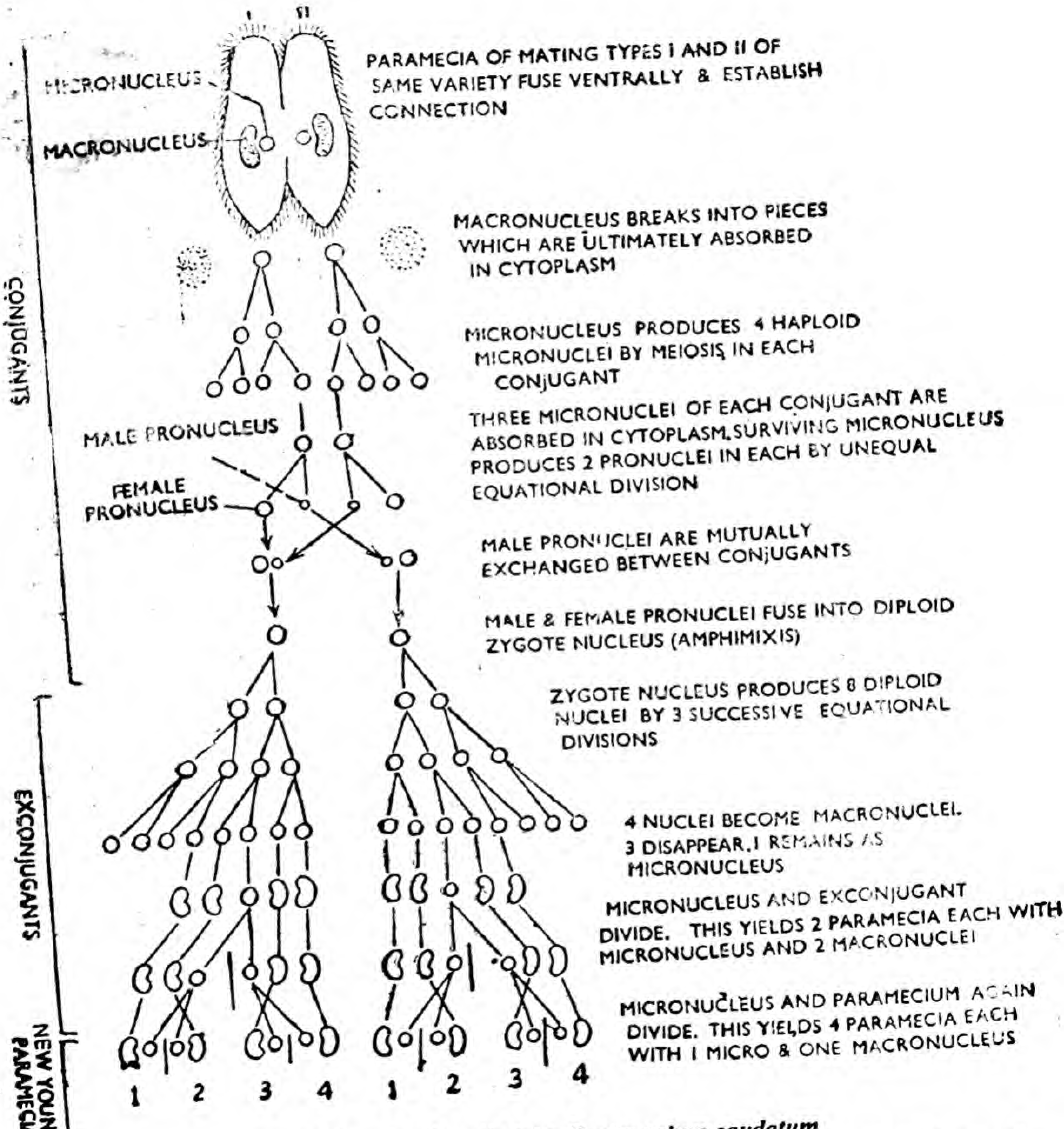


Fig. 8.14. Conjugation in *Paramecium caudatum*

(ii) Genetic significance of conjugation lies in the production of variations. Conjugation involves meiosis and fusion of nuclear matter

from two individuals of different mating types and this results in new combinations of characters in the organisms produced.

Conjugation does not result in multiplication as it seems and often taken to be. It begins and ends with two individuals. Multiplication that follows conjugation occurs by binary fission. Conjugation in *Paramecium*, thus, merely leads to reproduction. The term "reproduction" literally means the creation of a new individual and does not necessarily involve multiplication. Thus, it should apply equally to the making over the old individuals by the creation of new nuclei.

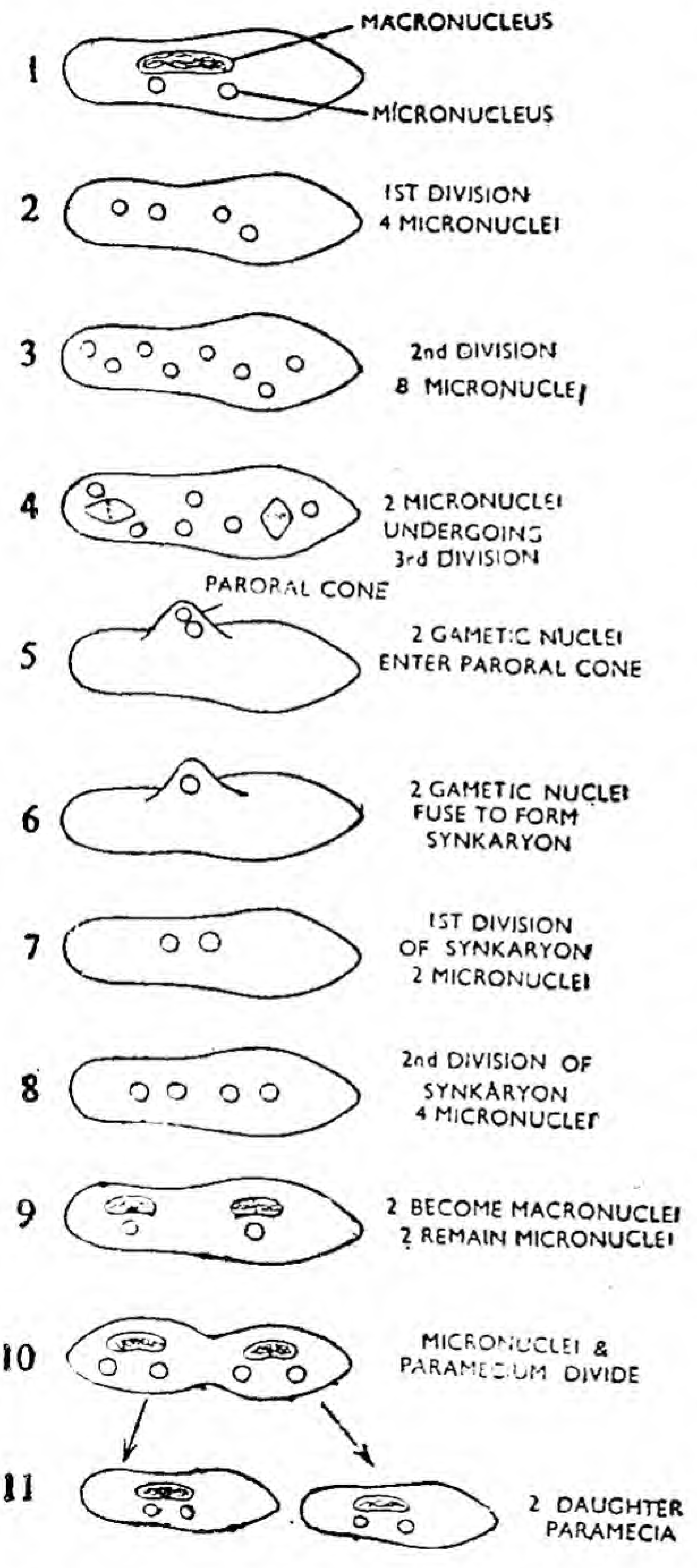


Fig. 8.15. Autogamy in *Paramecium aurelia*

3. Autogamy. (Fig. 8.15) Autogamy is known in *Paramecium aurelia*, which has two micronuclei instead of one.

(*a*) **Definition.** Autogamy is a process of reconstruction of nuclear apparatus involving the fusion of pronuclei of the same individual. It corresponds to self-fertilization in higher animals.

(*b*) **Procedure.** The macronucleus elongates and breaks up into fragments, which are ultimately absorbed in the cytoplasm. The micronuclei undergo two successive divisions, the first of which is reductional and the other equational. This produces 8 haploid micronuclei. Of these, a few (2-5) divide for the third time. Two micronuclei arising after the third division survive, while all others from the second and third divisions degenerate. The survivors pass into a small process, the **paroral cone**, formed near the mouth and behave as the gametic nuclei, fusing to form **the synkaryon.** The latter undergoes two successive divisions, producing

four nuclei, two of which become macronuclei and two micronuclei. The micronuclei divide and the organism splits into two daughter individuals, each receiving one macronucleus and two micronuclei.

(*c*) **Significance.** Autogamy has the same physiological significance as conjugation, *i.e.* it also results in rejuvenation of weakened organisms. But it has a different genetic significance. While conjugation makes paramecia heterozygous, autogamy again makes them homozygous. In other words, conjugation produces variations and autogamy gives pure lines.

4. **Hemixis.** Hemixis is a process of reconstruction of macronucleus without any change in the micronucleus. The meganucleus throws out a part of its chromatin, which is absorbed in the cytoplasm. This results in restoration of normal chromosomal set-up in the meganucleus and the organism starts normal life. Hemixis, thus, has the same physiological significance as conjugation and autogamy, *i.e.* rejuvenation, but it has no genetic role.

5. **Cytogamy.** Cytogamy is a process of nuclear reconstruction, which occurs in paired individuals, but involves the fusion of pronuclei of the same individual. It resembles conjugation in all details except that the conjugants separate without exchanging their male pronuclei. The male and female pronuclei of each individual fuse to form the synkaryon as in autogamy. Cytogamy is, thus, intermediate between conjugation and autogamy. It has the same genetic and physiological significance as autogamy.

6. **Endomixis.** Woodruff succeeded in keeping 15,000 generations of *Paramecium* alive over a period of 25 years without conjugation. During this period depression did set in at regular intervals ,but it was overcome by reconstruction of nuclear apparatus within a single individual without nuclear fusion. This process was named **Endomixis** by him. It corresponds to parthenogenesis. It is now held that endomixis does not occur.

Depression or Senile Decay

The micronucleus has the diploid number of chromosomes. The meganucleus, being formed from the micronucleus, also has the same number in the beginning. Later, however, it becomes polyploid by repeated division of its chromosome pairs. The amitotic division of the meganucleus during binary fission causes unequal distribution of its chromosomes among the daughter meganuclei. The resulting disturbance in the chromosome number of the meganucleus becomes more and more acute after each fission and ultimately impairs the power of the meganucleus to control the vegetative activities of *Paramecium*. This leads to an unhealthy state called **depression** or **senile** decay in which the organism finds it difficult to feed, grow and divide. The processes of conjugation, autogamy, hemixis and cytogamy replace the old abnormal meganucleus with a new normal one and this for a time, rejuvenates paramecia.

Adaptations to Environment

Minute size and light-grey colour of the body make *Paramecium* barely discernible against the background of mud below or sky above. Rapid locomotion afforded by cilia enables it to quickly find the necessities of life in its environment. The ability to perceive the nature of the water ahead and to quickly reverse the movement enables it to get out of danger without losing time. Thin pellicle facilitates diffusion of gases and nitrogenous waste material. The contractile vacuoles provide a wonderful mechanism for expelling out the excess of water. The device of anchoring by trichocysts makes possible for the organism to become stationary near a concentration of bacteria for feeding on them and at the same time to keep cilia beating, which is so essential for ingestion. High rate of multiplication maintains its population.

Advancement of Paramecium over Amoeba

Paramecium has a higher degree of differentiation than *Amoeba*. It has a constant shape ensured by firm elastic pellicle. It shows definite dorsal and ventral surfaces, clear lateral sides, and fixed anterior and posterior ends. It possesses permanent locomotory organelles in the form of cilia, which provide it a quick and efficient means of locomotion. There is a neuromotor system for co-ordination and control of the cilia. There is a well marked digestive system comprising permanent organelles like the oral groove, mouth, pharynx, oesophagus and anus. Cyclosis of the food-vacuoles along a constant path ensures fair distribution of food to all parts of the body. The crossed arrangement of cilia at the base of the oesophagus acts as a strainer and prevents the passage of larger food-particles. *Paramecium* possesses trichocysts for attachment to objects harbouring a large number of bacteria, which form its food. The trichocysts probably also act as the organelles of defence. *Paramecium* has a double set of osmoregulatory organelles. *i.e.* contractile vacuoles, whose efficiency has been further increased by the presence of the feeding canals. *Paramecium* exhibits nuclear dimorphism, the macronucleus controlling the vegetative activities and the micronucleus governing reproductive process. It has a tactile organelle in the form of a few sensory cilia at the hind end. Lastly, it has sexual reproduction in addition to the asexual one and there are mating types.

Comparison of Paramecium with Higher Animals

Paramecium approaches the higher animals in several respects. These are discussed in the following table.

TABLE 4.

Paramecium	Higher Animals
1. Has 2 types of nuclei : the meganucleus to control vegetative activities and the micronucleus to control sexual reproduction.	1. Have two types of cells : the somatic cells for vegetative activities, and the germ cells for sexual reproduction.
2. The meganucleus is mortal as it disintegrates, while the micronucleus is immortal as its product survives in the next generation.	2. The somatic cells are mortal as they perish with the individual's death, while the germ cells continue to live in the next generation.

3. The meganucleus of the next generation is formed from the micronucleus.	3. The somatic cells of the offspring are formed from the germ cells (zygote).
4. Gametic nuclei are haploid, being formed by meiosis.	4. Gametes are haploid, being formed by meiosis.
5. The two gametic nuclei that fuse to form the zygote nucleus are different morphologically as well as physiologically, one (male) being small and active and the other (female) large and passive.	5. The two gametes that fuse to from the zygote are different morphologically as well as physiologically, one (male) being small and active and the other (female) large and passive.
6. The two fusing gametic nuclei come from two individuals of different strains.	6. The two fusing gametes come from two individuals of different sexes.

Classification

The slipper animalcule is placed in the

Phylum	: **Protozoa**	Because it is acellular.
Sub-phylum	: **Ciliophora**	Because of cilia, nuclear dimorphism and conjugation.
Class	: **Ciliata**	Because cilia persist throughout life.
Order	; **Holotricha**	Because cilia are nearly equal-sized and in rows.
Family	: **Paramecidae**	Because it is free-swimming and has asymmetrical body with ventral oral groove.
Genus	: *Paramecium*	Because of slipper-like shape.
Species	; *Caudatum*	Because of having a colourless, relatively long and cylindrical body with pointed hind end, 2 contractile vacuoles fed by radiating canals and single micronucleus.

TEST QUESTIONS

1. Define conjugation. Give a brief description of conjugation in *Paramecium*. What is its significance ?

2. What is the period of depression and what is it due to ? How does *Paramecium* overcome this period ?

3. Make a labelled diagram to show the structure of *Paramecium*. What are the features in which it is more highly organised than *Amoeba* ?

4. Give an account of the sexual reproduction in *Paramecium*. Differentiate between amphimixis and endomixis.

5. Describe in detail the mode of locomotion in *Paramecium*. What functions are performed by the micronucleus, the meganucleus, cilia of the buccal groove, cyclosis of food-vacuoles and trichocysts ?

6. Discuss the process of nutrition in *Paramecium*.

7. Write notes on :
Osmoregulation, Mating Types, Autogamy, Binary Fission and Pellicle.

8. Enumerate adaptations of *Paramecium* to its environment.

CHAPTER **9**

Hydra

(The Fresh-water Polyp)

There are several species of *Hydra*. Two of these, namely, *Hydra vulgaris* and *Hydra oligactis* have been reported from India. The various species differ from each other only in minor details. The following account applies in general to all of them.

Study of *Hydra* is of special interest firstly because it serves well as introduction to Metazoa and secondly because in its adult organization it somewhat resembles the gastrula of higher animals, thereby suggesting that it represents a living counterpart of the remote ancestor of the higher animals.

Habitat and Habits

Hydra is a cosmopolitan animal. It inhabits cool and clean fresh-water of ponds, lakes and streams. It usually lives attached to various submerged objects like weeds, stones, sticks, etc. but it can move from place to place when occasion demands. It is a solitary creature though at times it may form a temporary colony by repeated budding. It is carnivorous in diet, feeding on small crustaceans, worms and insect larvae. It is itself fed upon by some worms and mollusks. It multiplies sexually as well as asexually.

Morphology

Hydra is a very small animal. It is, however, easily visible to the naked eye. Its size ranges from 2 to 20 mm. in different species.

Colour also varies from species to species. *Hydra vulgaria* is almost colourless, *Hydra oligactis* is brown, while *Chlorolorohydra virridissima* is green. The green colour of the last named species is due to the presence of a unicellular green alga (*Chlorella vulgaris*) in the body-wall.

The body of *Hydra* has the form of a hollow tube (Fig. 9. 1). Its proximal end is closed by a flat disc termed the **basal disc** or **foot**. The latter fixes the body to the substratum by a sticky secretion. The distal free end of the body has a small conical projection, the **hypostome** or **oral cone**, perforated at the apex by a circular aperture, the **mouth**. A ring of 4—12 fine hollow processes, the **tentacles**, surrounds the base of the hypostome. The number of tentacles differs between species and increases with the age of the animal. The size of the tentacles also varies with the species. They are shorter than the body in *Chlorohydra virridissima*,

slightly longer than the body in *Hydra vulgaris* and much longer than the body in *Hydra oligactis*. The tentacles are highly extensile and may stretch out from short blunt projections to extremely thin threads, 7 cm. or more long and hardly visible even with a lens. The tentacles are primarily meant for capturing the prey, but are also used for locomotion. The adult *Hydra* may bear buds and gonads on the surface of its body for asexual and sexual reproduction respectively.

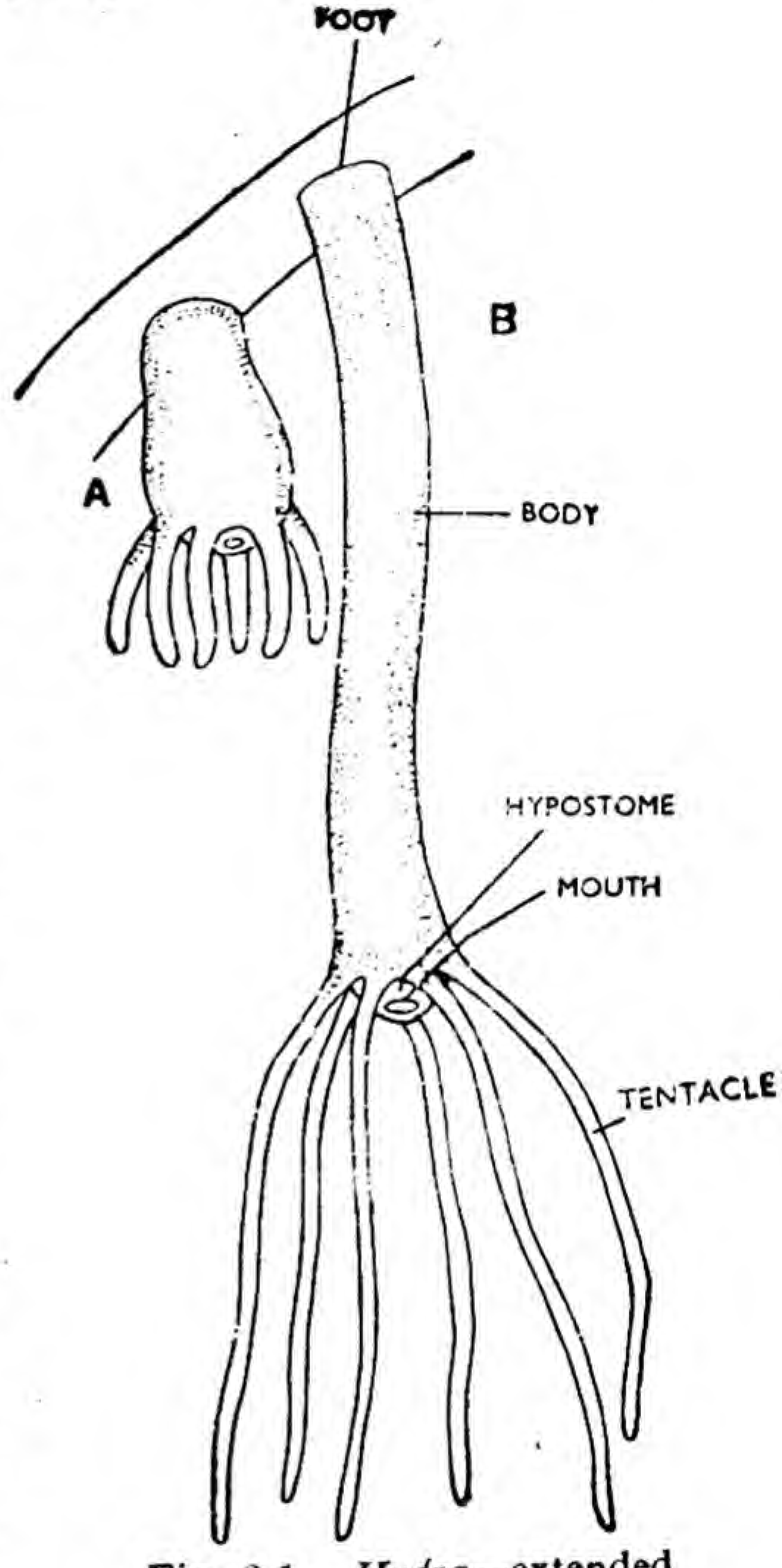


Fig 9.1. *Hydra*—extended and contracted

Symmetry

The line extending from the mouth to the basal disc forms the principal axis of the body. Any longitudinal section passing through this axis divides the body into two similar halves. Such a body is said to have **radial symmetry**.

Body-wall

The body-wall of *Hydra* consists of two layers of cells (Figs. 9.2. and 9.3). The outer layer is thin and is called the **epidermis**[1]. The inner layer is about twice as thick as the outer layer and is termed the **gastrodermis.**[2] Each of these layers contains several types of cells. Everywhere between the epidermis and the gastrodermis is a thin layer of a non-cellular jelly-like material, the **mesogloea**. The mesogloea is, however, lacking in the central part of the basal disc. The tentacles have all the three layers.

1. Epidermis. The epidermis is protective, sensory, muscular, secretory and reproductive in function. It comprises seven types of cells : **epitheliomuscular cells** or **myo-epithelial cells, interstitial cells, nematoblasts** or **cnidoblasts** or **stinging cells, nerve-cells, sensory cells, gland cells,** and **germ cells** (Fig. 9.4 and 9.5).

(*i*) **Epithelio-muscular Cells**. These form the greater part of the epidermis (Fig. 9.4). They are large cone-shaped cells having their broad ends directed outwards and narrow ends facing inwards. The broad ends of these cells meet one another to form a continuous covering over the body. Their outer portions contain a layer of granules, which secrete

*1 and 2. These layers were formerly called ectoderm and endoderm, but strictly these terms refer to the undifferentiated germ layers of an embryo and therefore cannot properly be applied to the highly differentiated layers of an adult animal.

a thin protective **cuticle** outside. Their narrow ends leave gaps between them and are drawn into processes termed the **muscle-processes or muscle-tails.** The latter contain contractile fibril, the **myoneme,** and lie against the mesogloea parallel to the body. They act as longitudinal

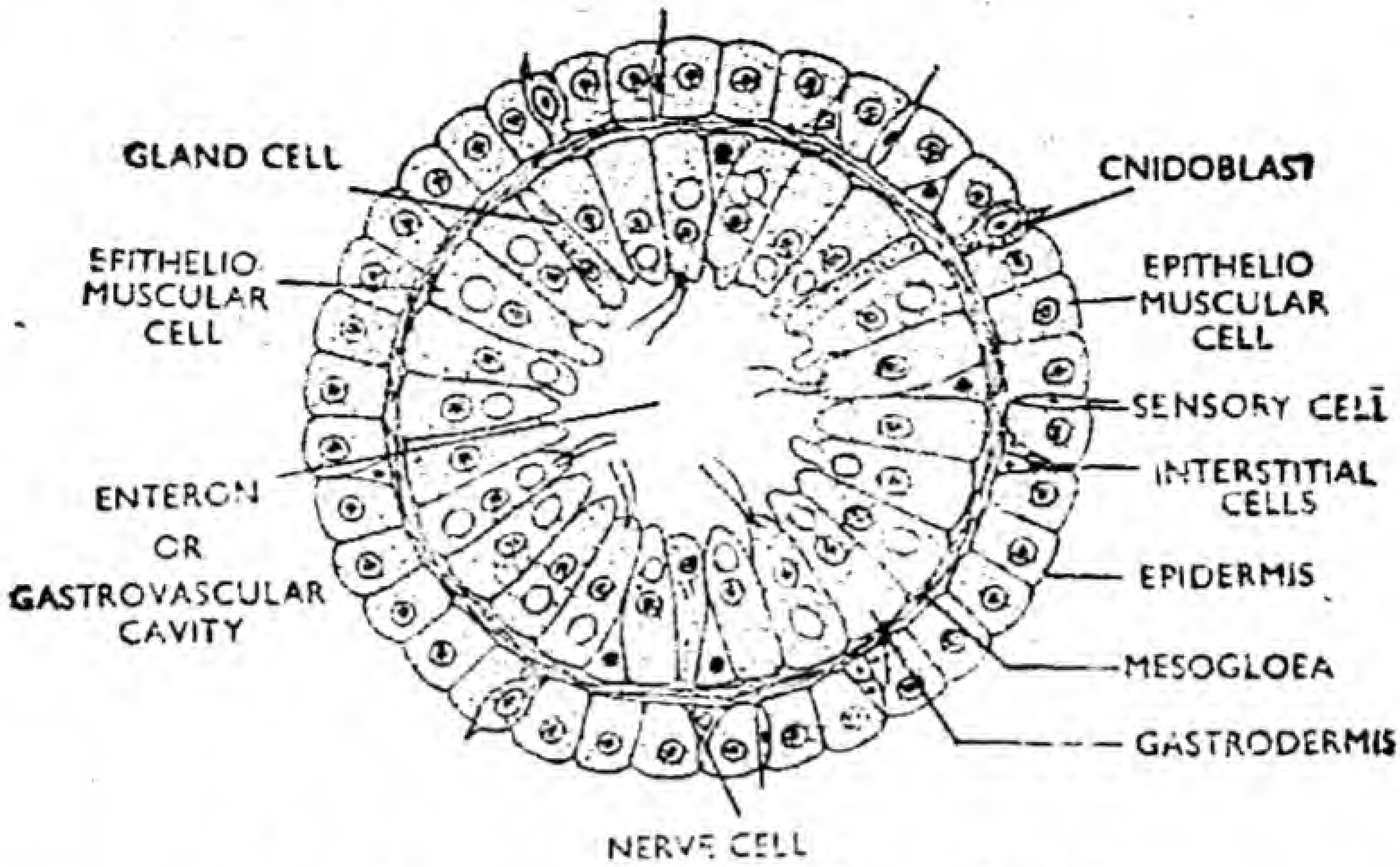


Fig. 9.2. Transverse section of *Hydra*

muscles, which increase and decrease the body length by their extension and contraction respectively.

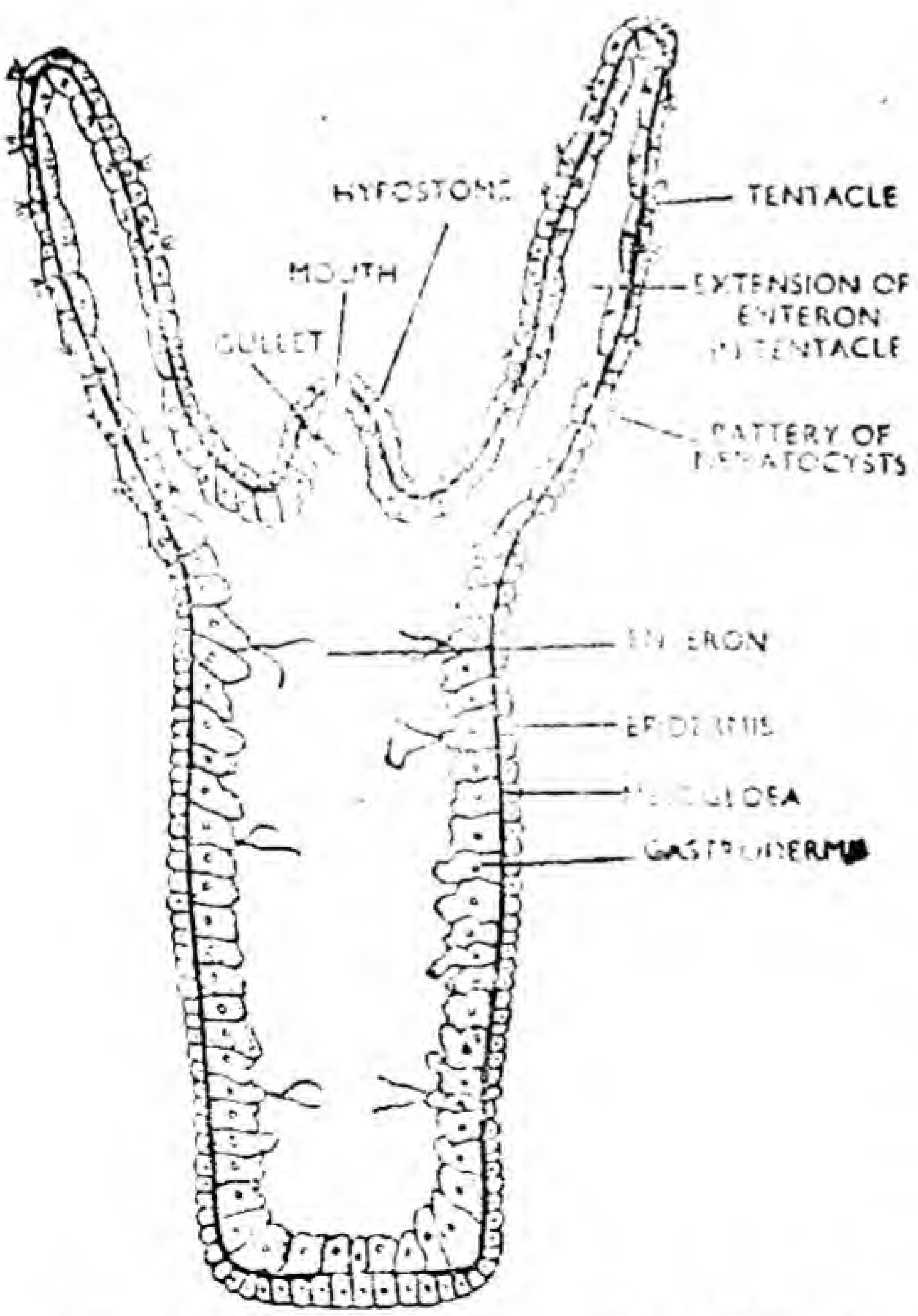


Fig. 9.3. **Vertical** section of ***Hydra***

(*ii*) Interstitial Cells. These occur in groups filling up the spaces between the inner narrow ends of the epithelio-muscular cells. They are small rounded cells, each with a prominent nucleus. They are not specialised for any particular function. They can divide and transform themselves into other types of epidermal cells.

(*iii*) **Nerve-cells.** These are irregular in shape. Each consists of a small **cell body** with a nucleus and a number of fine branching processes or **fibres.** The fibres of the adjacent nerve-cells approach each other so closely that they appear to form a sort of nerve-net outside the mesogloea. The fibres may be in contact or intertwined round each other, but there is no protoplasmic continuity between them. The nerve-net is, thus, not continuous. The nerve-net serves to transmit impulses from one part of the body to another.

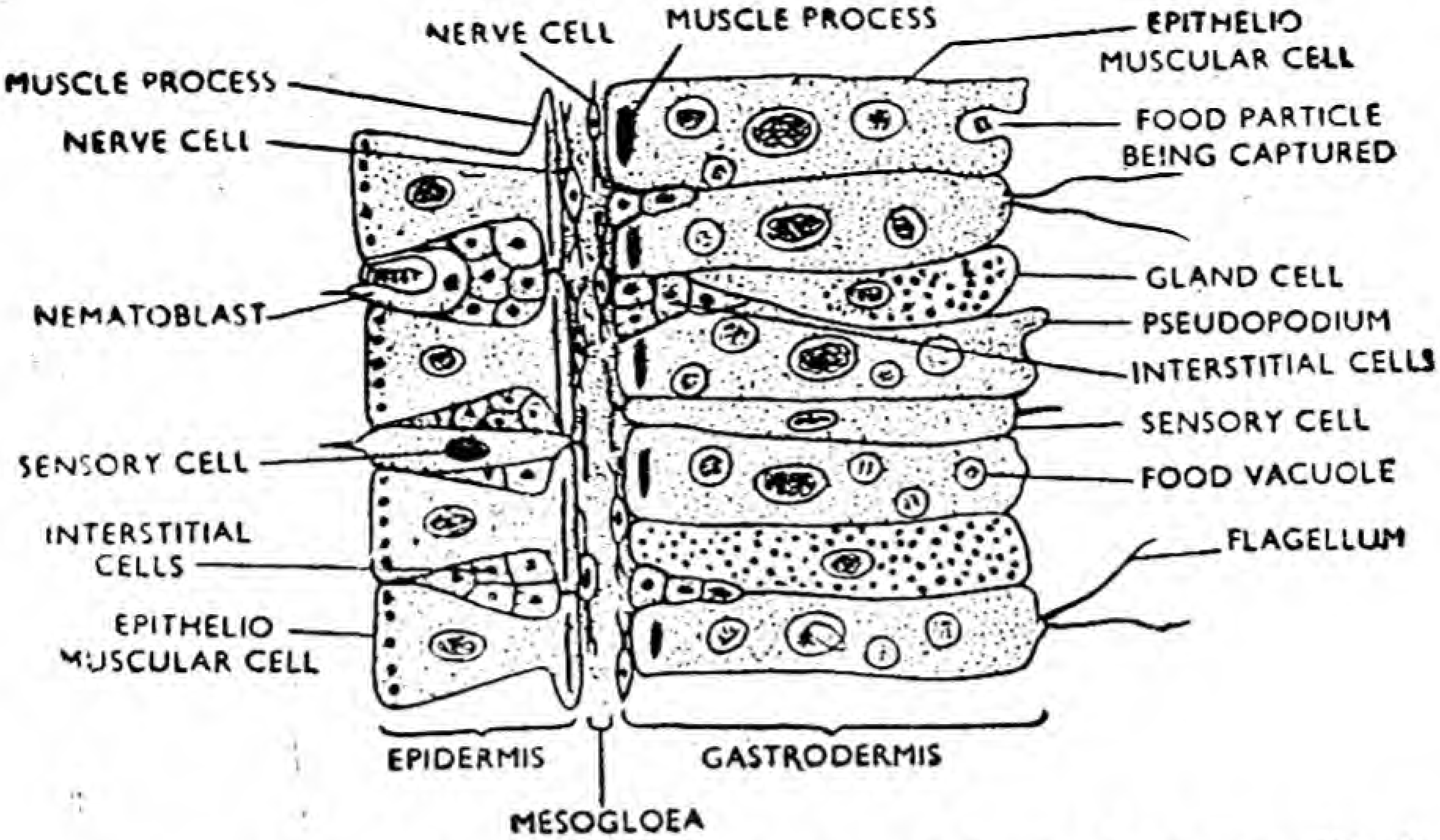


Fig. 9.4. Part of vertical section of *Hydra* (highly magnified)

(*iv*) **Sensory Cells.** These are scattered among epithelio-muscular cells. They are long narrow cells, each bearing a minute process at the free end and prolonged into a nerve-fibre at the other end. The sensory cells are sensitive to external stimuli, like contact, light, temperature and chemicals.

(*v*) **Gland Cells.** These occur on the basal disc and around the rim of the hypostome. Those on the disc secrete a sticky substance for attachment to the substratum. Some of them produce a gas to form a bubble, which serves to detach *Hydra* and to raise it to the surface. The gland cells round the rim of the hypostome secrete mucus to facilitate swallowing of larger food particles.

(*vi*) **Nematoblasts or Cnidoblasts.** These lie in the epidermis everywhere except the basal disc. A nematoblast is a large pear-shaped cell with its nucleus lying on one side (Fig. 9.6). It bears at its free end a small sensory bristle, the **cnidocil,** set in a slight projection of the cell. It develops in it a remarkable structure known as the **nematocyst.** The nematocyst consists of a large ovoid double-walled capsule and a long slender

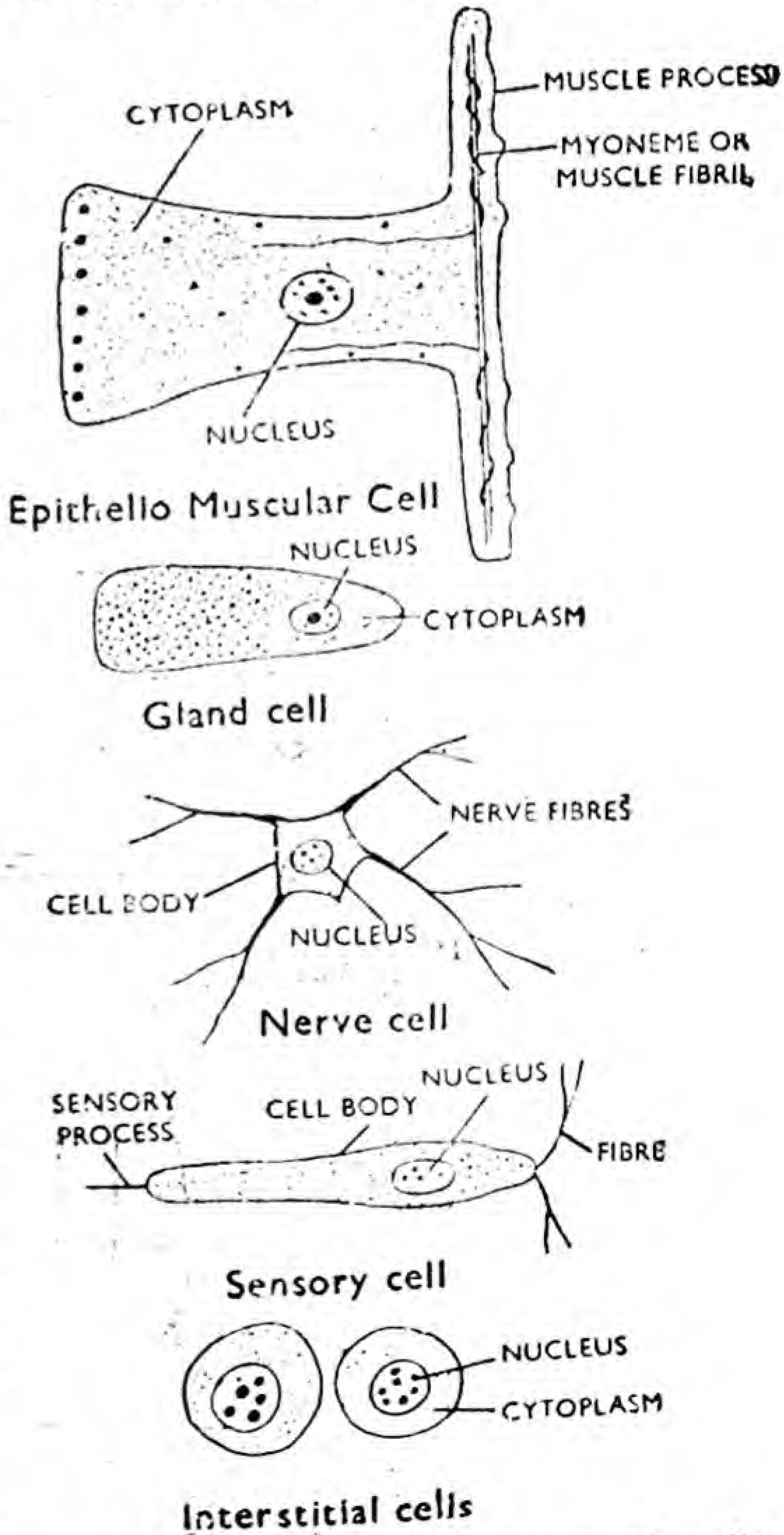
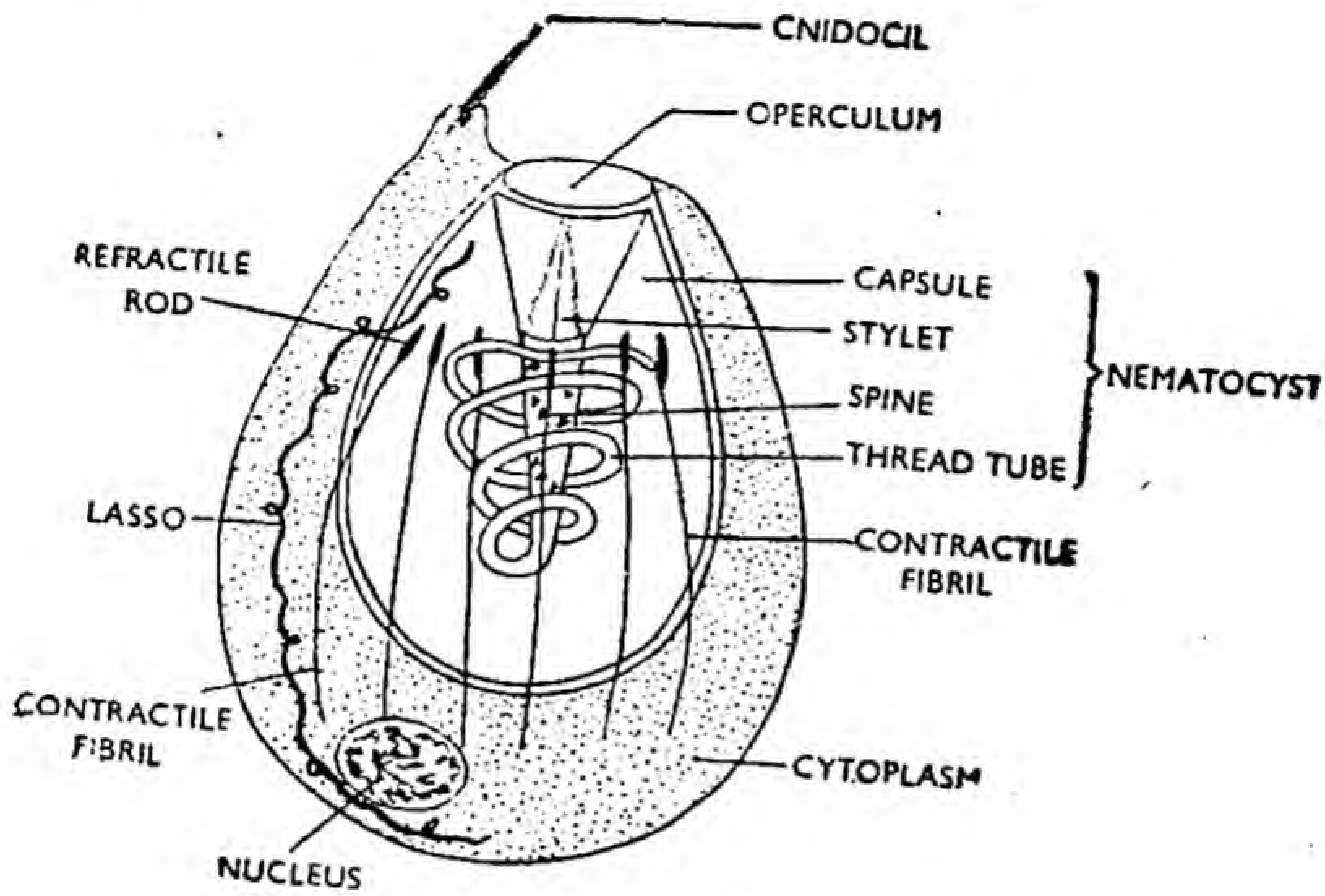


Fig. 9.5. Principal types of cells in the body-wall of *Hydra*

thread-tube. The capsule is closed at its outer end by a flat lid or **operculum.** It is filled with a poisonous fluid, the **hypnotoxin.** A number of short refractile rods lie on the outer surface of the capsule. They are connected with long contractile fibrils that pass to the base of the capsule. A thread called **lasso** arises from the base of the cnidoblast and is inserted on the capsule. It prevents the capsule



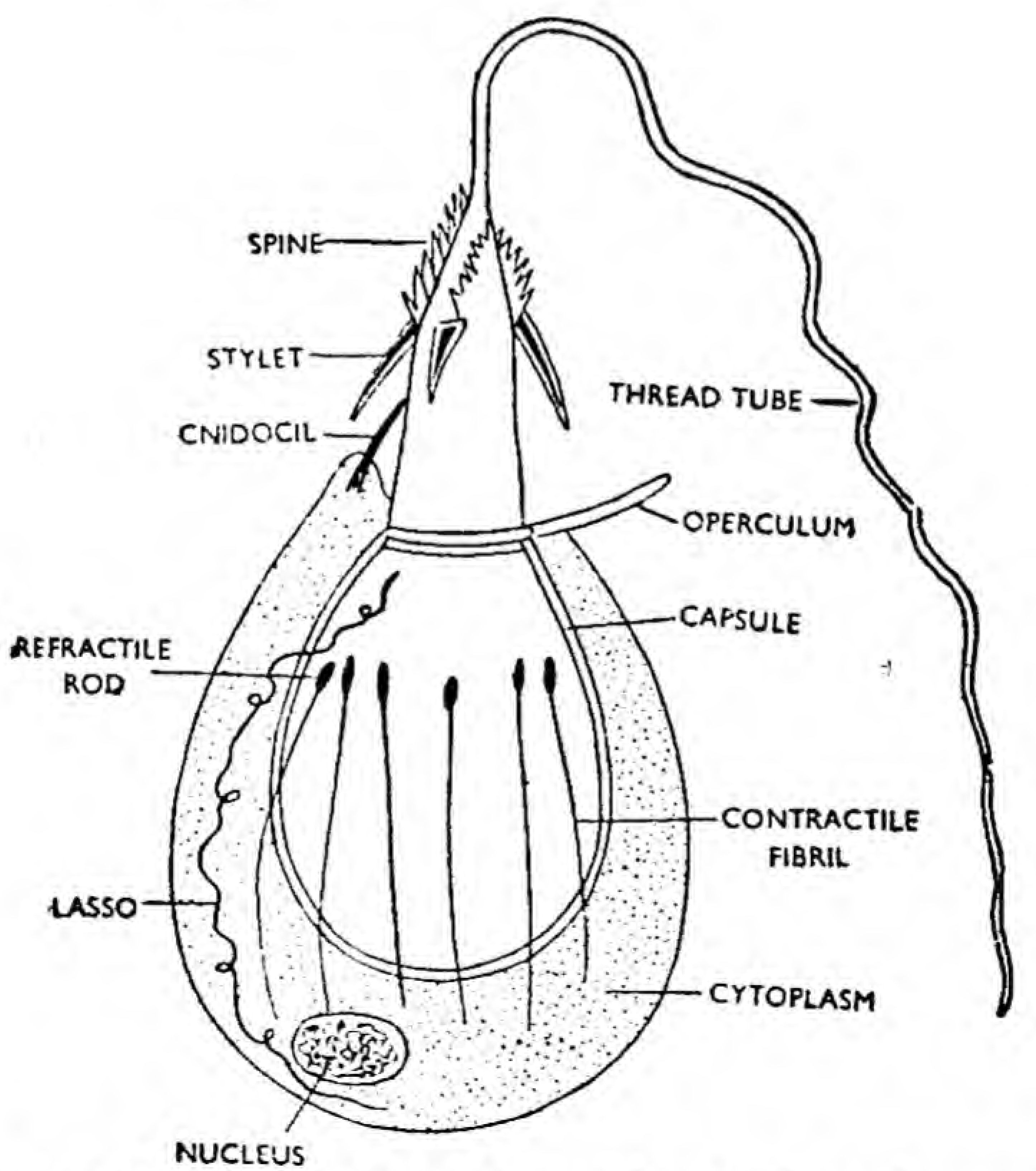


Fig. 9.6. Upper—Cnidoblast with undischarged nematocyst. Lower—the same after discharging the nematocyst

from being thrown out at the time of discharge. The thread-tube is wide at the base. This part of the thread-tube is called the **butt**. It bears three large pointed **stylets** or **barbs** and a few spiral ridges with minute **spines**. When undischarged, the butt lies inverted in the capsule, the stylets and spines being on its inner side and the thread tube coiled round it.

The nematocysts of *Hydra* are of four kinds : **Penetrants** or **stenosteles**, **volvents** or **desmonemes**, **large glutinants** or **holotrichous isorhizas** and **small glutinants** or **atrichous isorhizas** (Fig. 9. 7). The penetrants are the largest, have armed thread-tube and inject poisonous

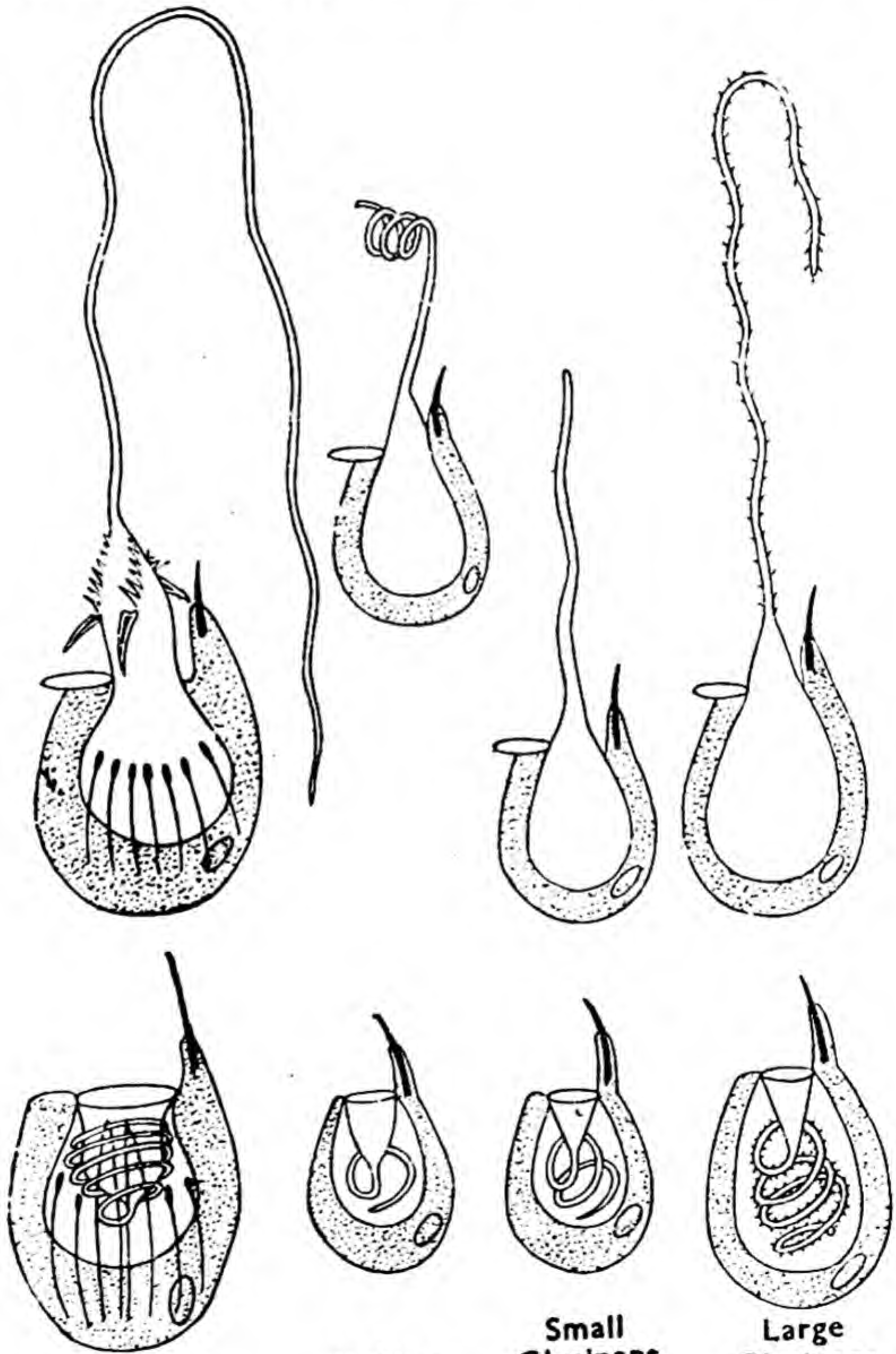


Fig. 9.7. Types of nematocysts of *Hydra*—shown undischarged in the lower row and discharged in the upper row

fluid in the body of the victim. A penetrant has been described above in detail. The volvents have small pear-shaped capsule and a short thick unarmed thread-tube closed at the distal end. Its thread-tube lies in the capsule in a single loop but, when discharged, coils tightly around the bristles or other projections on the body of the prey. The glutinants have oval capsule and a long sticky thread-tube of uniform diameter and open at the distal end. They lack the butt. Their thread-tube is unarmed in the small glutinants and armed with a spiral row of minute spines in the large glutinants. In both types, the thread-tube, when discharged, adheres to the body of the prey.

On the body, the cnidoblasts occur mostly wedged in between the outer ends of the epithelio-muscular cells. On the tentacles and hypostome, however, they lie within the epithelio-muscular cells, which are then known as the host cells. A host cell contains a group of cnidoblasts. Such a group is termed a battery.

The cnidoblasts have no connection with the nerve-cells or sensory cells. They discharge their nematocysts by direct stimuli and thus act as independent effectors. Exact nature of the stimulus that evokes discharge of nematocysts is not known with certainty. On proper stimulation, the operculum of the nematocyst capsule opens and the thread-tube is quickly everted. In this operation, first the base of the thread-tube with stylets and spines comes out and then the rest of the tube rapidly turns inside out. The thread-tube penetrates the body of the victim and hypnotoxin is injected into it. This kills or paralyses the victim.

Once discharged, the thread-tube cannot be withdrawn nor can another nematocyst be developed in the same cnidoblast. Such cnidoblasts migrate into the enteron where, they are digested.

The nematoblasts develop from the interstitial cells of the epidermis in the middle part of the body. From here the young nematoblasts pass into the enteron through the mesogloea and gastrodermis. From the enteron they again reach the epidermis when and where needed. On arriving at their final position, the nematoblasts become mature and functional.

All types of nematocysts help in capturing the food. Besides this, the penetrants aid in keeping off the enemies and the glutinants in locomotion.

(*vii*) **Germ Cells.** These are produced in certain regions of the body by repeated divisions of the interstitial cells of the epidermis. Tha **germ** cells give rise to the gametes for sexual reproduction.

2. **Gastrodermis.** This is primarily absorptive, digestive and muscular in function, though it also helps in the circulation of food. It comprises five types of cells : **epithelio-muscular cells, gland cells, nerve-cells, sensory cells** and **interstitial cells** (Fig. 9. 4).

(*i*) **Epithelio-muscular Cells.** These form the major part of the gastrodermis. They are columnar cells with outer ends drawn out into **muscle-processes** which contain fine contractile fibrils. These muscle-processes, unlike those of the similar cells of the epidermis, run at right angles to the

body. They, thus, act as the circular muscles, which cause variation in the thickness of the body by their expansion and contraction. The circular muscle processes around the mouth and bases of the tentacles act as sphincters to close these openings. The inner free ends of the epithelio-muscular cells may put out pseudopodia or flagella. The pseudopodia ingest solid food-particles from the gastrovascular cavity for digestion in food-vacuoles within the cells. In this respect they behave exactly like *Amoeba*. The flagella, by their lashing movements, keep the food circulating in the gastrovascular cavity. The epitheliomuscular cells also absorb food digested in the gastrovascular cavity.

(*ii*) **Gland Cells**. These are smaller than the epithelio-muscular cells among which they are scattered. They lack muscle processes and may not reach the mesogloea. They also bear one or two flagella. They are abundant in the body and the hypostome, fewer in the basal disc, and absent in the tentacles. They secrete a digestive juice into the gastrovascular cavity.

(*iii*) **Interstitial Cells**. These resemble those in the epidermis. They, in fact, migrate from the epidermis and lie in groups between the outer ends of epitheliomuscular cells. They develop into other types of cells when needed.

(*iv*) **Nerve-cells**. These also resemble their counterparts in the epidermis. They are, however, far less in number. They form the so-called nerve-net inside the mesogloea. Perhaps the epidermal and gastrodermal nerve-nets are interconnected by fibres passing through the mesogloea.

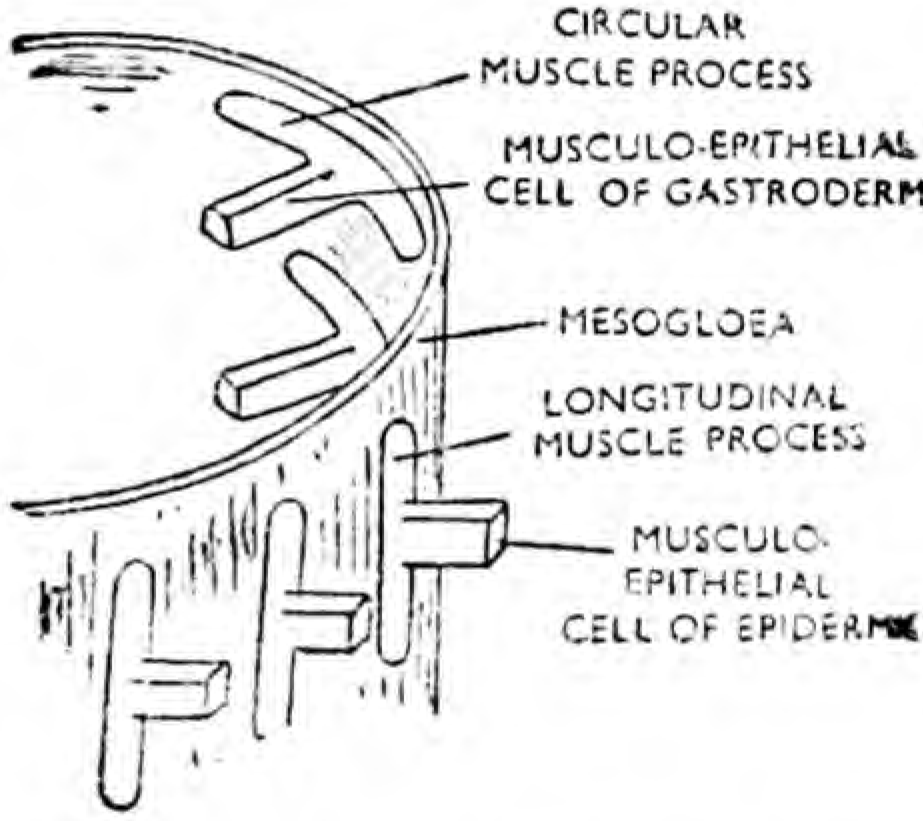


Fig. 9.8. Diagram showing the direction of the muscle processes of the two layers of cells in *Hydra*

(*v*) **Sensory Cells**. These are fewer in the gastrodermis than in the epidermis.

3. **Mesogloea**. The mesogloea is a thin sheet of jelly-like material secreted by both epidermis and gastrodermis between them. It is present everywhere except the central part of the basal disc. It is traversed by nerve-fibres and contains no cells. Some migrating cells may be found in it at times. It serves as a basement membrane for the cells of both the layers. (Figs. 9.2, 9.3 and 9.4). It also provides surface for the attachment of muscular processes and its elasticity helps in the extension of the body after contraction. It, thus, serves in *Hydra* as a supporting layer or **skeleton**.

Musculature

Hydra possesses two layers of contractile muscle-processes. These are attached to the opposite surfaces of the supporting mesogloea (Figs. 9.4 and 9.8). The muscle-processes of the outer layer arise from epithelio-muscular cells of the epidermis and are longitudinal in

arrangement. The muscle-processess of the inner layer spring from the epithelio-muscular cells of the gastrodermis and are disposed in a circular manner around the body. The circular muscle-processes contract slowly, while the longitudinal muscle-processes can contract quickly. These muscle-layers of *Hydra*, thus, foreshadow in a dim way the visceral (unstriped) and skeletal (striped) muscles of higher animals. Musculature provides a high degree of mobility to *Hydra*.

Movements and Locomotion

Though fixed by its basal disc or foot to various objects in water, *Hydra* can move its body and tentacles and can, on occasions, also travel from place to place.

Movements. Movements of *Hydra* comprise shortening, elongation and bending of the body and the tentacles and are of two types: **spontaneous** in response to internal stimuli and **induced** in response to external stimuli. Spontaneous movements may be seen in an undisturbed specimen. At short intervals, the body or tentacles or both contract quickly and then slowly expand in a new direction. A hungry individual shows greater activity than the well-fed one. These movements bring the animal in a new part of its surroundings, where it may find more food and oxygen. All these movements of the body are brought about by the muscle processes of the epidermal and gastrodermal cells. Its shortening and thickening is caused by the contraction of the longitudinal muscle processes borne on the epidermal cells, while its elongation and narrowing is affected partly by contraction of the circular muscle-processes given out from the gastrodermal cells and partly by the elasticity of the mesogloea. Bending of the body results from shortening of one side and elongation of the other side.

Locomotion. *Hydra* moves from place to place in several ways like **gliding, dragging, looping, walking and floating**.

1. **Gliding**. Gliding is used for covering short distances on a smooth surface. In gliding, *Hydra* slowly creeps along the substratum in an upright position with the help of pseudopodia put out by the epidermal cells of the basal disc or foot.

2. **Dragging.** This method is employed for changing location in a limited area. The tentacles are attached some object, the basal disc is released and the body is pulled towards bject by the contraction of the tentacles.

3. **Looping** (Fig. 9.9). Looping is a normal mode of progression for travelling long distances The body is extended and bent over in the direction of movement to bring the oral end in contact with the substratum. The tentacles are fixed by means of the small glutinant nematocysts. The foot is now released, drawn up closer to the oral end and fixed again. The tentacles are then freed and the body resumes an upright position. This looping action of *Hydra* resembles that of a leech or measuring worm.

Sometimes the foot is put down beyond the tentacles so that the animal appears to somersault (Fig. 9.10).

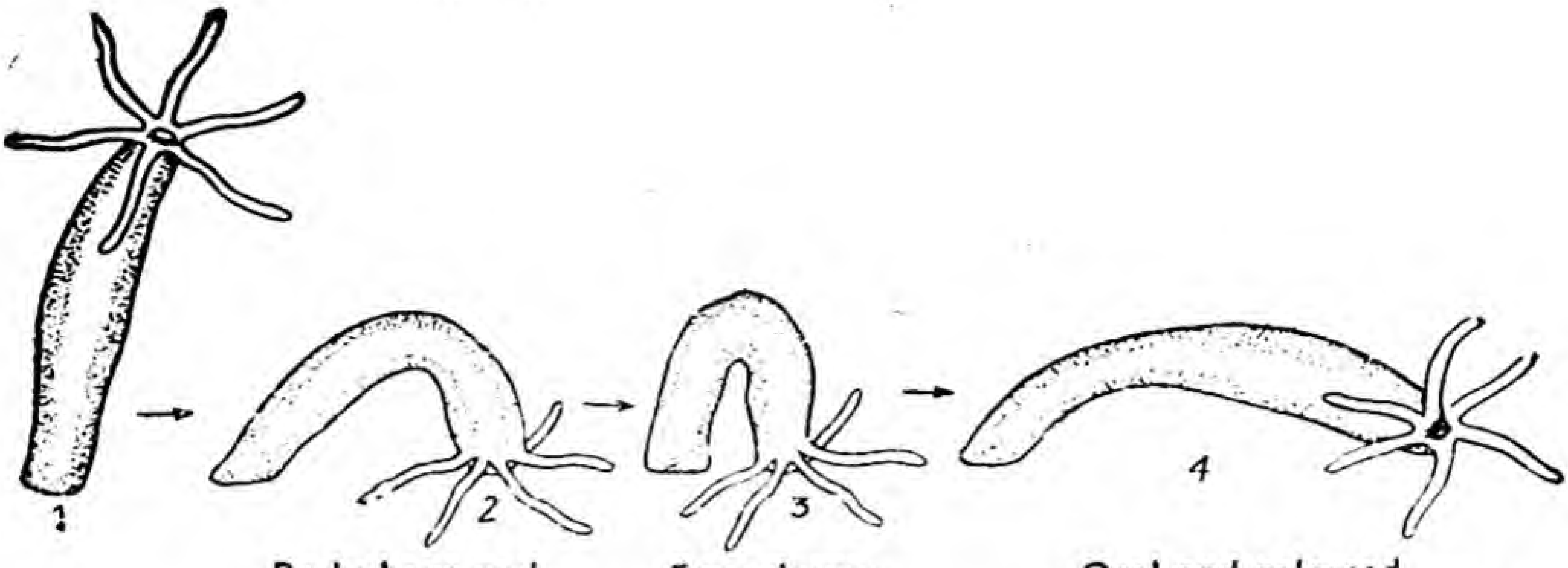


Fig. 9.9. Looping in *Hydra*

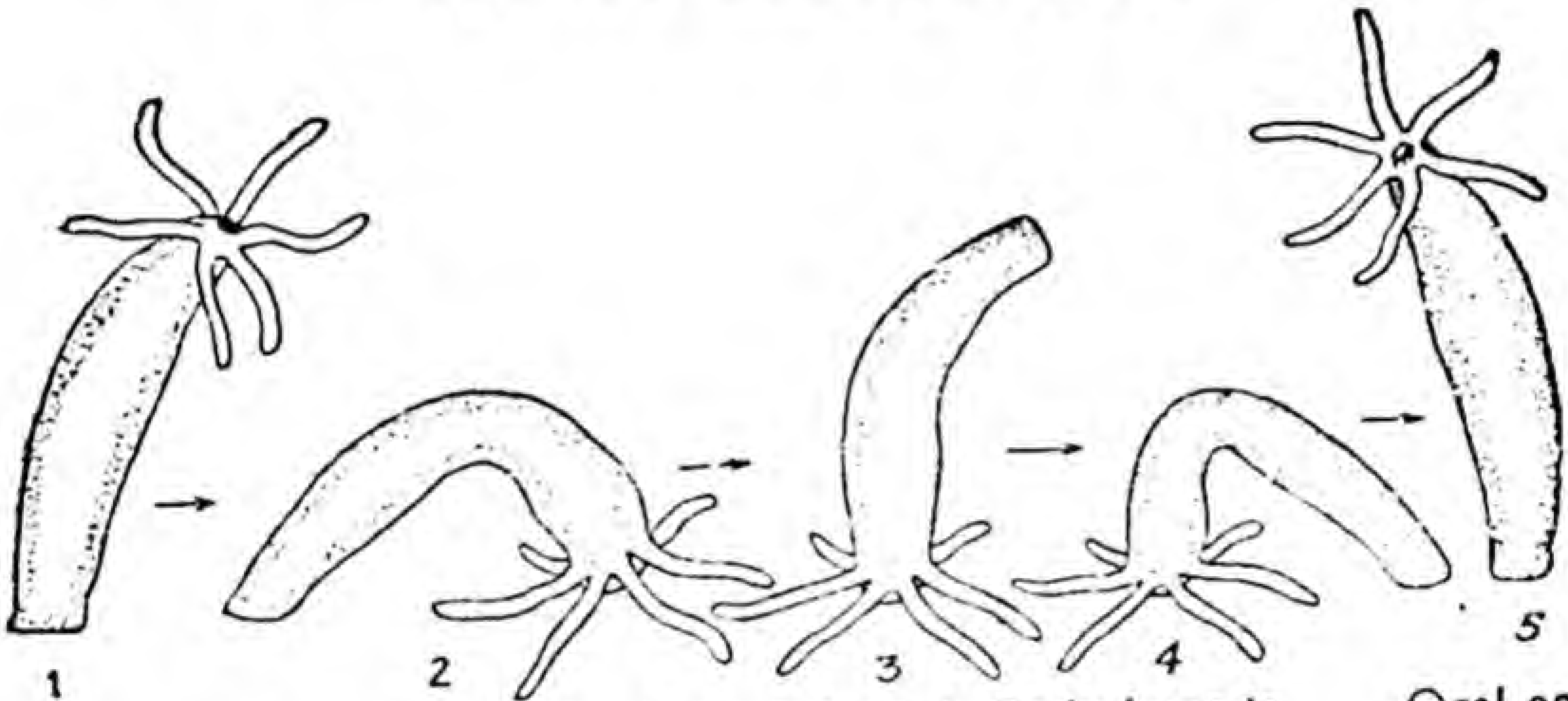


Fig. 9.10. Somersaulting in *Hydra*

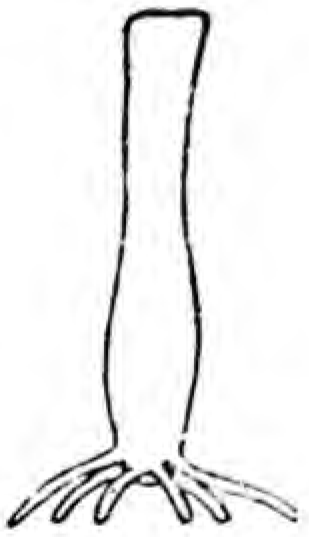


Fig. 9.11. Walking in *Hydra*

Fig. 9.12. Floating in *Hydra*

4. **Walking.** In walking, *Hydra* travles in an upside-down position, using its tentacles as legs (Fig. 9.11).

5. **Floating.** Occasionally, *Hydra* secretes in the mucus of the basal disc a gas bubble, which detaches it from the substratum, brings it upwards and helps it in **floating** passively at the surface (Fig. 9.12).

Nutrition

(*a*) Food. *Hydra* is carnivorous. It feeds on living animals only. Its food consists principally of water-fleas, worms and insect larvae.

(*b*) **Ingestion**. *Hydra*, when attached by its foot, normally keeps its body and the tentacles well extended. In this position it waves its tentacles over a considerable hunting territory. When some tiny animal comes in contact with a tentacle, the nematocysts of that region are at once discharged. The penetrants puncture the victim and inject hypnotoxin, which paralyses it. The volvents coil up round the bristles or other projections on the victim's body to hold it fast until ready for swallowing. The viscid surface of the tentacles also prevents the escape of the prey. The tentacle holding the captured prey bends towards the mouth. Other tentacles also bend over the prey and may assist in quietening it by using their nematocysts. All the tentacles now shorten and bring the prey just above the mouth. The mouth opens widely before the prey touches it. It opens by relaxation of the sphincter muscle. The edge of the mouth gradually closes around the prey to swallow it. Mucus secreted by the gland cells within the mouth helps the process of swallowing. The prey, thus engulfed, is forced down into the gastrovascular cavity by contraction of the hypostome.

(*c*) **Reaction to food**. The mere contact of the prey with the tentacle is not enough to cause food-taking reaction in *Hydra* A chemical stimulus is also necessary. This chemical stimulus is provided by a substance called **glutathione**, which is universally present in all animal tissue fluids. This substance is released when the body of the prey is punctured by penetrant nematocysts. This is why *Hydra* feeds on living animals only. The dead animals and the living animals below the nematodes have no tissue fluid and are, therefore, not eaten by *Hydra*.

(*d*) **Digestion**. The prey may remain alive in the gastrovascular cavity for some time. It is, however, soon killed by the secretion of the gland cells present in the gastrodermis. This secretion contains proteolytic enzyme, which partly digests the protein component of the food. This digestion of food which occurs in the gastrovascular cavity is called the **extracellular** or **intercellular digestion**. Such a digestion is found in most multicellular animals. The partly-digested food is broken into fine particles by thrashing of flagella and churning movements produced by expansion and contraction of the body-wall. This also brings about proper mixing of food and digestive juices for the better action of the latter on the former. The food-particles are ingested by pseudopodia put out by the free ends of the epithelio-muscular cells in the gastrodermis and come to lie in food-vacuoles within their cytoplasm. Here the food is digested in much the same way as in *Amoeba* and other Protozoa. This is known as the **intracellular digestion**. It is to be specially noted that *Hydra* combines digestive methods of forms both lower and higher than itself. The probable reason for the retention of the intracellular digestion is that a sufficient concentration of digestive juices is not established in the gastrovascular cavity, which almost freely communicates with the outside water. Digestion in food-vacuoles shows early acidic phase and later alkaline phase. Digestion of protein is completed in the food-vacuoles. Lipids are digested entirely in the food-vacuoles. *Hydra* seems to be unable to digest starch.

(e) Distribution. The food digested in the gastrovascular cavity is absorbed into the gastrodermal cells. From here some of it diffuses through the mesogloea into the epidermal cells. Certain gastrodermal cells after capturing the food particles, break off from their neighbouring cells and either move in an amoeboid manner or are carried passively by currents set up by the flagella into the tentacles where they are ingested. Even fragments of gastrodermal cells also distribute the food in a similar way.

(f) Assimilation. The food absorbed into the cells is transformed into protoplasm. This is called assimilation. A part of the food, chiefly the oil globules, is stored in the epidermal cells for use in the production of energy.

(g) Egestion. The indigestible residues are cast off by the gastrodermal cells into the enteron. From here they are expelled out through the mouth by a series of violent contractions of the body-wall. The debris falls some distance away from the animal.

Growth

Growth in *Hydra* occurs by division of all types of cells except the cnidoblasts. The latter are formed from the interstitial cells.

Respiration

There are no special organs for respiration in *Hydra*. The gaseous exchange necessary for respiration takes place over the entire surface of the body. Both epidermis and gastrodermis are in contact with water and no cell is far removed from it. Oxygen diffuses into the cells from the water and carbon dioxide diffuses out of the cells.

Excretion

Hydra lacks definite organs for excretion. The waste nitrogenous matter, mainly ammonia, formed in the cells during metabolism is lost by diffusion into the surrounding water.

Osmoregulation

Epidermis and gastrodermis of *Hydra's* body present a large surface to the water. This, as mentioned above, facilitates the exchange of gases and elimination of waste nitrogenous matter. This also favours influx of water into the cells by diffusion. *Hydra* cannot avoid this absorption of water into its cells. It can, therefore, be concluded that it must be in possession of some mechanism for getting rid of excess water in order to maintain the water balance of its body. This mechanism of osmoregulation, is, however, unknown.

Behaviour

Hydra prefers to live in a region of moderate light intensity, avoiding both very strong and weak light. It generally inhabits cool water with a temperature of 20°C or less. It responds to strong mechanical stimuli like jarring the watch-glass, agitating the surface of water, touching with a fine rod, by contracting its body. Its sensitivity to strong chemicals is also indicated by contraction.

Reproduction (Figs. 9. 13, 9.14 and 9.15).

Hydra produces new individuals by asexual as well as sexual means.

1. Asexual Reproduction. Asexual reproduction occurs chiefly during summer months when food is abundant. It takes place by budding. Small protuberances arise from the body-wall near the foot (Fig. 9.14). These are termed the **buds**. Before budding starts, food accumulates in the gastrodermal cells of that region. Each bud encloses an extension of the enteron of the parent and its wall consists of three layers, namely, epidermis, mesogloea and gastrodermis, which are continuous with the respective layers of the parent body. The bud grows in size and soon becomes cylindrical. Tentacles develop one by one at its free end by evagination. Mouth appears in the centre of the tentacles. This converts the bud into a small *Hydra*. A constriction appears at the junction of the young with the parent. The constriction deepens and finally the young *Hydra* is set free. The young *Hydra* rises to the surface of water and floats there for two or three days. During this period it is carried away from the parent by water-currents. Ultimately it settles down and fixes itself to some object with the aid of its foot. It then grows and becomes adult in due course of time.

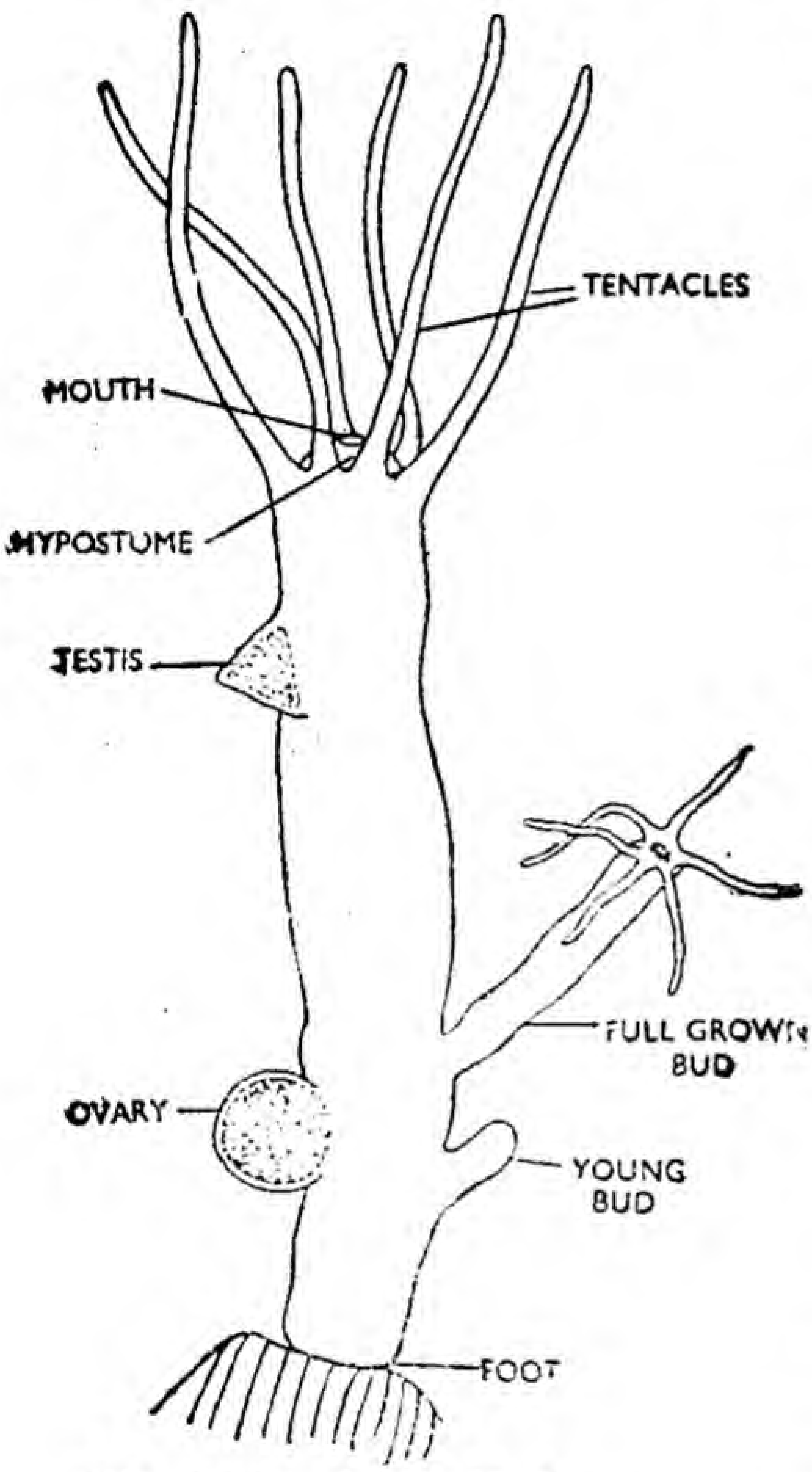


Fig. 9.13. Adult *Hydra* with buds and gonads

Several buds may arise simultaneously on a single parent and these may in turn produce secondary buds on them so that a sort of colony is formed. This condition is, however, short-lived and soon the various buds separate as independent individuals.

2. Sexual Reproduction (Fig. 9.15). Sexual reproduction generally occurs in autumn. Most species are unisexual or dioecious, *i.e.* bear male and female sex organs on separate individuals. A few are, however, bisexual or monoecious, *i.e.* bear organs of both the sexes on the same individual. Whatever the case, the sex organs or gonads are not permanent. They disappear after shedding the gametes and may appear at a new place next year.

(*a*) **Male Organs**. A large number of interstitial cells gather at a place, pushing the epidermis into a conical elevation. This gives rise to the male organ or **testis**. Several testes develop in this manner on a single

individual. They are formed on the distal half of the body (Figs. 9.13 and 9.15). The interstitial cells inside the testes behave like the **primordial germ cells**. They multiply by mitosis and produce innumerable cells, the **spermatogonia**. The latter, by an elaborate process of spermatogenesis, give rise to the haploid male gametes, the **spermatozoa** or **sperms**. A

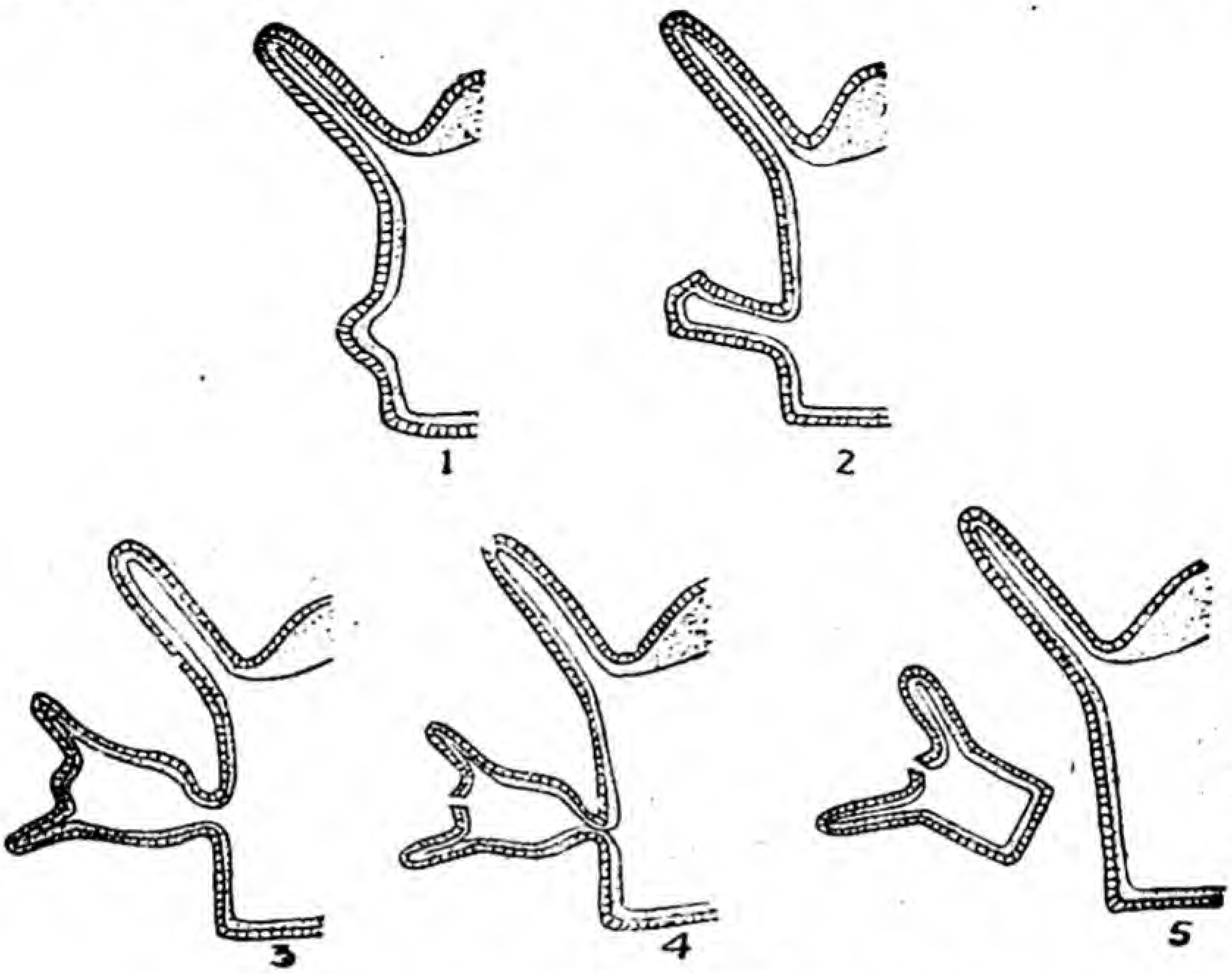


Fig. 9.14. Bud formation in *Hydra*

sperm consists of a minute rounded **head** and a long vibratile **tail**. The mature spermatozoa escape through a pore formed at the tip of the testis and swim about in water in search of the female gamete. They remain active from 1—3 days.

(*b*) **Female Organ.** Normally one individual bears a single female organ or **ovary**. It develops like a testis but is rounded in shape and appears on the proximal half of the body (Figs. 9.13 and 9.15). At an early stage it consists of an aggregation of interstitial cells surrounded by greatly-stretched epidermal cells. The interstitial cells of the ovary are termed **oogonia**. One oogonium, generally the more centrally-placed one, grows in size. At first it receives food like the other epidermal cells but later disintegration and absorption of adjacent interstitial cells provide nourishment. The oogonium by a process of oogenesis forms the haploid female gamete or **ovum**. The ovum is a large rounded eell packed with yolk granules. For sometime it remains covered by epidermal cells. The latter ultimately break and the ovum gets exposed.

(*c*) **Fertilization**. Cross-fertilization occurs in *Hydra*. This is ensured by **protandry**, *i.e.* maturation of sperms earlier than ova. The sperms from the testes of one *Hydra* swim to an ovum or egg developed on another *Hydra*. One of them penetrates the ovum and the two completely fuse to form a diploid **zygote**. Fertilization normally occurs within two

hours and if it fails to take place within 24 hours, the ovum becomes sterile.

(*d*) **Development.** (Fig. 9.15). Fertilization is almost immediately followed by **segmentation** or **cleavage**, which is holoblastic or total, *i.e.* the cleavage cuts through the entire cell, and regular or equal, *i.e.* the cells formed are similar Soon a spherical embryo, termed the **blastula,** is formed. It encloses a fluid-filled cavity, the **blastocoel**, walled by a single layer of similar cells, the **blastomeres.** The latter dlvide in

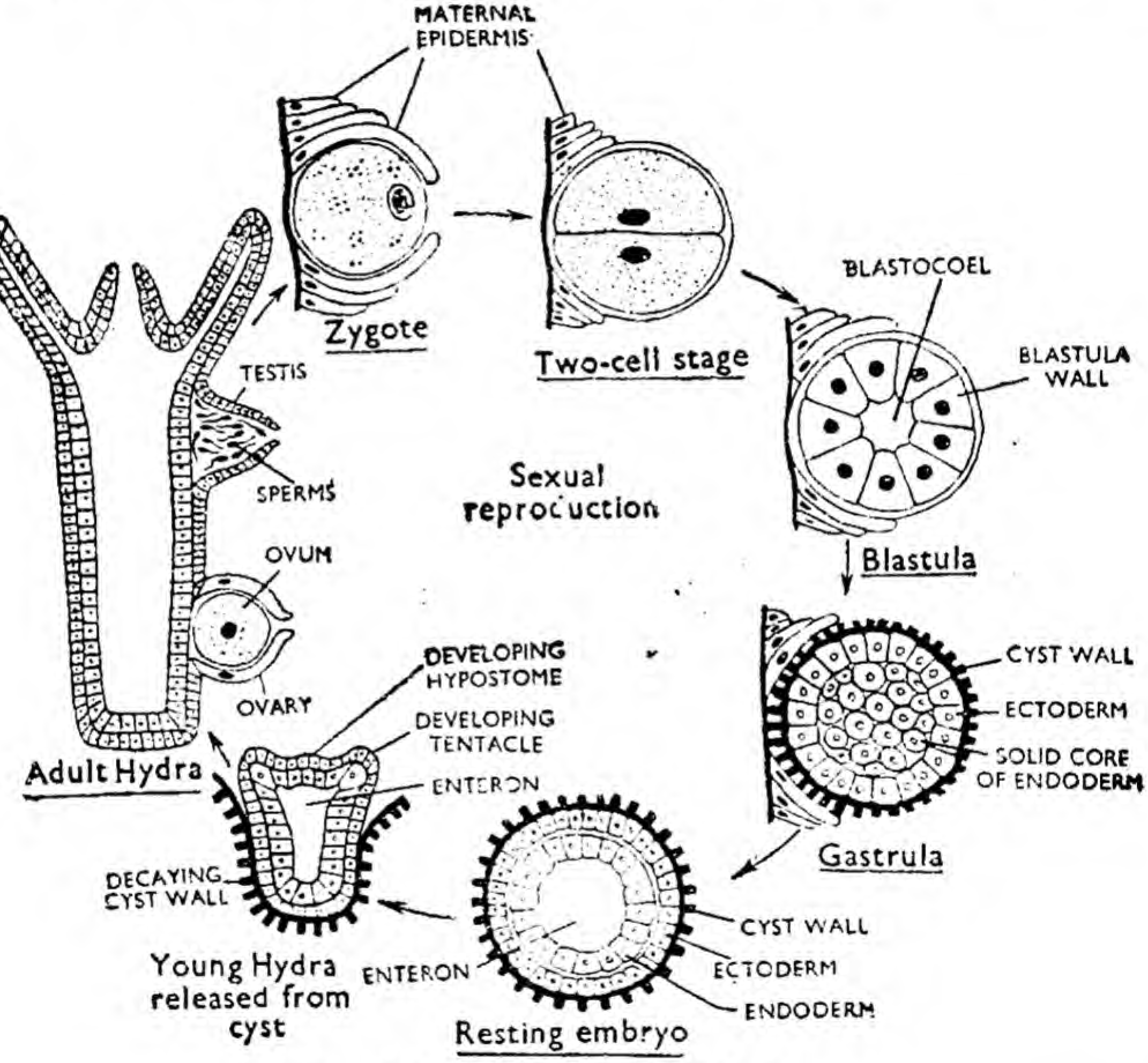


Fig. 9.15. Life-history of *Hydra*

tangential planes and the new cells formed fall into the blastocoel, filling it completely. The embryo is now called the **gastrula** or **stereogastrula.** Its outer layer of cells is known as the **ectoderm** and the inner solid mass as the **endoderm**. Later, a new cavity, the **enteron**, appears by a split in the central mass of endoderm cells and the gastrula becomes hollow. In the meantime the ectoderm secretes a horny covering, the **cyst** or **theca,** for protection against temperature extremes and desiccation. The cyst is smooth in some species, with low projections in others. The encysted embryo breaks from the parent and falls to the bottom of the pond, where it undergoes a period of rest for several weeks. The parent often dies after releasing the embryo.

(*e*) **Dispersal.** The resting cysts are dispersed by water currents, in mud on the feet of water animals and by air if water dries up altogether.

(*f*) **Hatching.** (Fig. 9.15). With the approach of favourable conditions, development is resumed. Mesogloea is secreted between the ectoderm and the endoderm. Differentiation of cells occurs in these layers, which acquire the characteristics of epidermis and gastrodermis respectively. The cyst breaks and a tiny embryo comes out. Mouth appears at the tip and tentacles grow around it. The young *Hydra* starts feeding and grows in size. For some time, it floats at the surface of water to be dispersed by water currents. Ultimately it fixes itself to some object.

Regeneration

Regeneration is the ability of living organisms to replace their lost parts. Among animals this power was first discovered in *Hydra* by Trambley, an Englishman, in 1740. Since then it has been found to occur in all the animals, though in varying degrees. It is more pronounced in the lower than in the higher animals. In man, for example, it is restricted to healing of injured tissues like skin, muscles, bones, blood-vessels and nerves, the lost parts being incapable of regeneration. The inability of complex animals to regenerate the lost parts is the price of their specialization.

Hydra, being a lower animal, shows regeneration to an amazing degree. If cut into two or more parts, each part grows into a complete individual. Even fragments as small as 0·004 mm. in diameter can grow into entire animals provided that they contain a portion of both epidermis and gastrodermis. Pieces too small to regenerate fuse to form larger lumps, each of which then develops into a new *Hydra*. If only the head is split into two, a peculiar two-headed *Hydra* is formed. *Hydra* turned inside-out becomes normal by migration through the mesogloea of epidermal and gastrodermal cells to their original positions.

Grafting

Grafting is very easy in *Hydra*. Oral end of one specimen can be successfully united with the aboral end of another to form a new individual.

Morphological and Physiological Differentiation

All living objects exhibit certain fundamental activities, like movement, metabolism, irritability, growth and reproduction, by which they differ from the non-living objects. Some of these, like the group Protozoa which includes *Amoeba, Plasmodium* and *Paramecium*, perform these fundamental life functions in a very simple way within the limits of their small, simple, acellular bodies. The position is, however, different in others, the Metazoa or many-celled animals. Here the body is large, multicellular and differentiated into a number of parts which are specialised to carry on the different life activities. In *Hydra*, for instance, the foot fixes the animal to the substratum, the tentacles capture food and help in locomotion, the mouth is used for the ingestion of food and for the egestion of wastes, the epidermis is protective,

muscular, sensory and reproductive in function and the gastrodermis is concerned with secretion, digestion and circulation. This phenomenon of carrying on different functions by different parts of the animal body is known as the **morphological** (structural) and **physiological** (functional) **differentiation** or **division of labour.** This differentiation is relatively meagre in *Hydra* but progressively increases in the higher animals like earthworm, cockroach, frog and rabbit.

Adaptations to Environment

Highly extensile tentacles enable *Hydra* to hunt for prey over a considerable area around it and thus compensate for the sedentary mode of life. Intracellular digestion enables it to make full use of the captured food in the absence of sufficient concentration of digestive juices in the gastrovascular cavity due to its free communication with the outside water. Extremely thin body-wall facilitates respiration and excretion by diffusion. Ability to keep off the predators with the help of nematocysts, to move or float away from unfavourable spot and to regenerate lost parts quickly contribute to its survival. Rapid multiplication by budding maintains its population during favourable conditions. Formation of resistant cysts provides a good means of survival during periods of drought to which its fresh-water habitat is periodically subjected and of dispersal to new localities.

Classification

The fresh-water polyp described above belongs to the

Phylum :	**Coelenterata**	Because it is diploblastic, has cnidoblasts and contains coelenteron with a single outlet.
Class :	**Hydrozoa**	Because its gonads are ectodermal.
Family :	**Hydridae**	Because it has only polyp form.
Genus :	*Hydra*	Because it is non-green.
Species :	*H. vulgaris.*	Because it is colourless.

TEST QUESTIONS

1. Describe in detail the structure of the body-wall of *Hydra.*
2. Give an account of reproduction in *Hydra.*
3. Write all you know about nutrition in *Hydra.*
4. Discuss the various modes of locomotion found in *Hydra.*
5. Write short notes on :—

Radial symmetry, Nematoblasts, Regeneration, Mesogloea and Budding.

6. Describe the following processes about *Hydra.*

(*a*) Excretion. (*b*) Growth. (*c*) Dispersal

(*d*) Ingestion of Food. (*e*) Locomotion.

7. Name the species of *Hydra* found in India. Make a bold labelled sketch of L.S. or T.S. through the body of *Hydra* showing details of cells.
8. Give an account of the habitat, habits and external characters of *Hydra.*

CHAPTER **10**

Obelia geniculata

(The Sea-fir)

It has been learnt in the previous chapter that *Hydra* develops buds, which later detach from it as young individuals. If these buds do not break off from it, a colony of individuals would be formed. This actually occurs in many coelenterates related to *Hydra*. Such forms are termed **hydroids** (*Hydra*-like) and their individuals, **zooids**. *Obelia* is one of the hydroids.

Habitat and Habits. *Obelia geniculata* is a marine hydroid. It is found all over the world in the shallow coastal waters up to a depth of about 72 metres. Its colony is sedentary, attached to various objects in the sea like rocks, weeds, shells, etc. The colony is branched like a plant and is often known as a **zoophyte**. Food consists of tiny organisms that are captured with the help of special stinging cells. Reproduction is asexual as well as sexual. Life-history includes a free-swimming larva called the **planula**.

COLONY

Morphology

Colony of *Obelia geniculata*, like *Hydra*, has radial symmetry. It is creamy-white or light brown in colour and attains a height of about 30 mm. To the naked eye, the colony presents the appearance of a delicate fur-like growth of fine branching filaments (Fig. 10.1). On closer examination, the colony is found to consist of two types of filaments; the horizontal and the vertical. The horizontal filaments attach the colony to the substratum and are collectively called the **hydrorhiza**. The vertical filaments arise from the hydrorhiza at intervals and are known as the **hydrocauli**. The latter branch in a cymose manner, each branch giving rise to the next after ending in a zooid. This makes the hydrocauli grow in a zig-zag manner with a short side branch at each bend or node. The apparent side branches are not true branches. A true branch extends from the base of the zooid to the point of origin of the preceding side branch. At the apex of each hydrocaulus lies a **bud** that will later develop into a zooid. The entire colony encloses one continuous cavity, the **gastrovascular cavity** or **coelenteron**, bounded by two layers : the external tough **perisarc** and the internal soft coenosarc (Fig. 10.2). The **coenosarc** is the living part of the colony as it consists of cells. The perisarc, on the other hand, is a dead

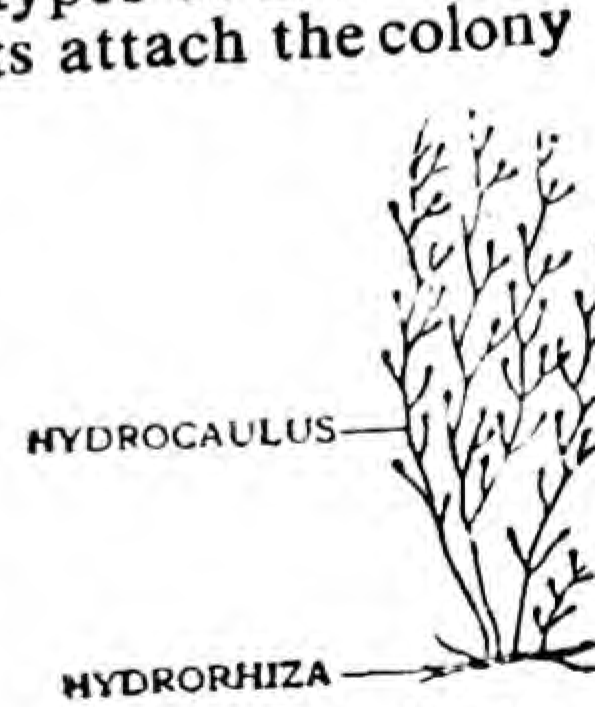


Fig. 10.1. *Obelia*

non-cellular layer. It is merely a chitinous secretion of the coenosarc. It functions as the protective covering for the inner living part. It also gives support to the erect filaments. In the newly-formed parts of the colony, the perisarc lies in contact with the coenosarc, but later the two layers separate from each other by a fluid-filled space, except at certain places where the coenosarc extends to meet the perisarc. The perisarc

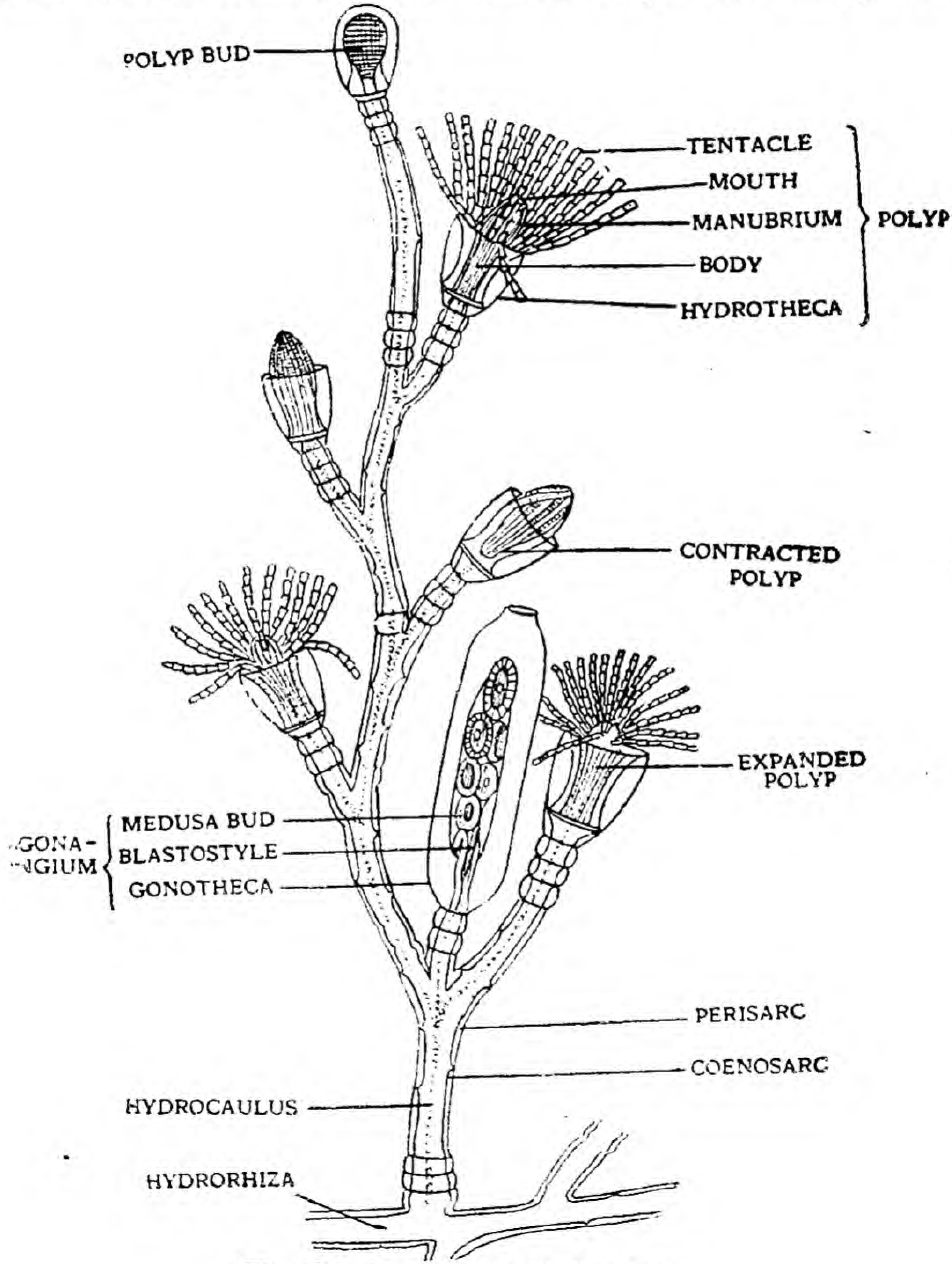


Fig. 10.2. A portion of *Obelia* colony

has ring-like grooves or **annuli** below each zooid as well as near the bends of the hydrocaulus. These grooves impart flexibility to the otherwise stiff perisarc.

Obelia colony develops three types of zooids, namely, **polyps, blastostyles** and **medusae.** This phenomenon of producing more than one type of individuals by an animal is termed **polymorphism.** The zooids differ from one another in structure as well as in function so that polymorphism is accompanied by the division of labour.

Polyp. The polyp, also called the **hydranth,** resembles *Hydra* in general appearance and structure. It has a cylindrical body with a conical projection, the **manubrium** or **hypostome,** at the distal end (Figs. 10.2 and 10.3). The manubrium is about one third of the total length of the zooid. It is perforated at its tip by an aperture, the **mouth.** A circlet of about 2 dozen fine processes, the **tentacles,** surrounds the base of the manubrium. The mouth leads into a small cavity in the manubrium and thence into a spacious cavity present in the body of the polyp. The cavity of the polyp is continuous below with the gastrovascular cavity in the rest of the colony.

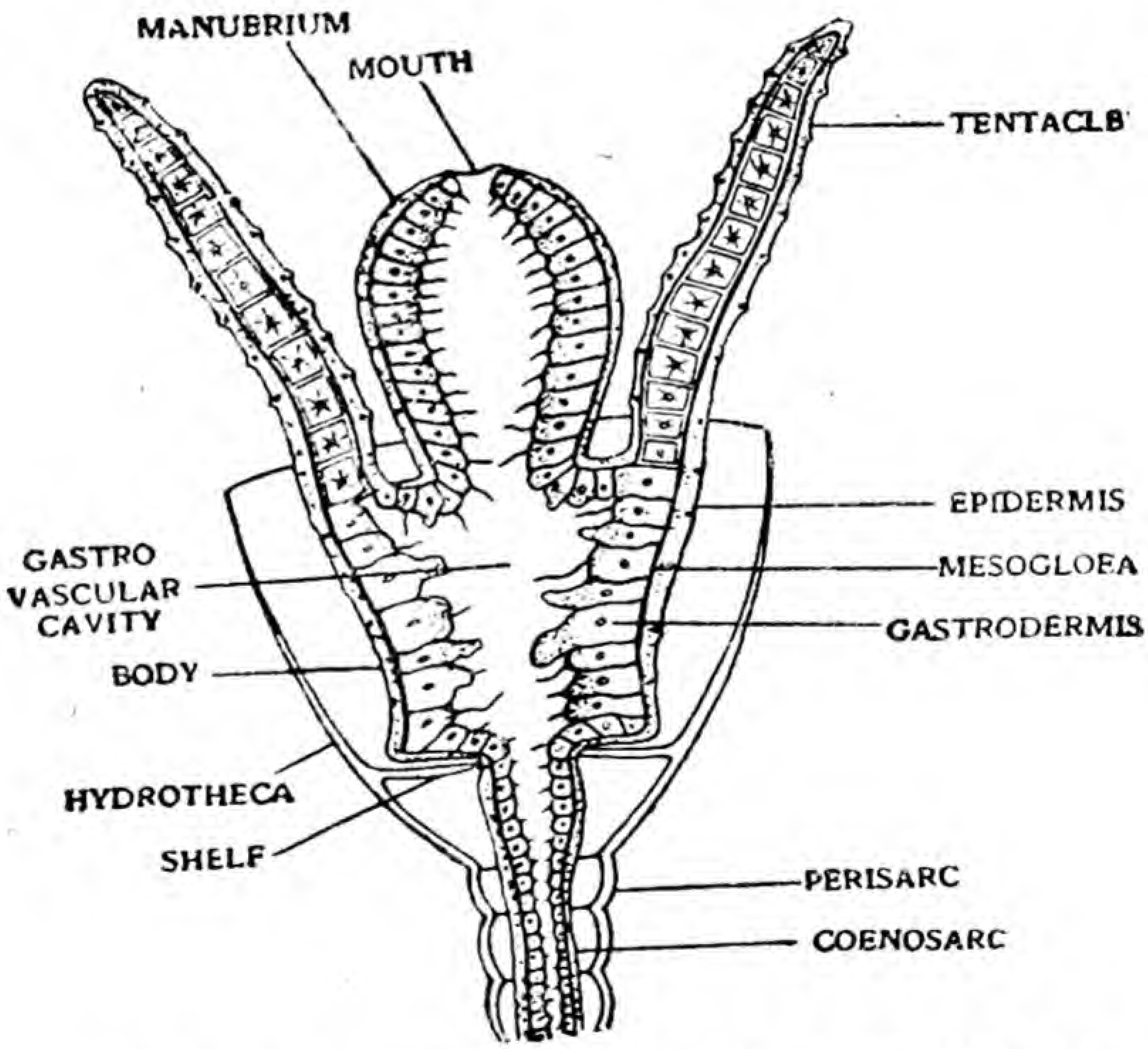


Fig. 10.3. Vertical section of the polyp of *Obelia*

The perisarc of the branch that bears the polyp expands to form a transparent, vase-like protective covering round the polyp. This is called **the hydrotheca.** The hydrotheca is open at its distal end so that the polyp may easily retract into or protrude out of it as the occasion demands. In a contracted polyp, the tentacles are shortened and folded over the manubrium. The inner surface of the hydrotheca at its base

projects inwards as a cir. ular shelf perforated in the centre. The polyp rests on the shelf and is continuous with the coenosarc of the colony through its central aperture.

The body-wall of the polyp consists of two layers of cells : the outer thin **epidermis** and the inner thick **gastrodermis** (Figs. 10.3 and 10.4). The two layers are continuous at the edge of the mouth. Between these two layers of cells is a thin sheet of non-cellular gelatinous material, the **mesogloea.**

1. **Epidermis.** The epidermis is protective, sensory, muscular, secretory and reproductive in function. It is covered by a delicate cuticle and comprises five types of cells : **epitheliomuscular cells or myo-epithelial cells, interstitial** or **indifferent cells, nematoblasts or cnidoblasts** or stinging cells or nettle cells, **nerve cells,** and **sensory cells.**

(*a*) **Epithelio-muscular Cells.** The epithelio-muscular cells form the greater part of the epidermis. They are large cone-shaped cells having their broad ends directed outwards and narrow ends facing inwards. The broad ends of these cells meet one another to form a continuous covering over the body, interrupted, of course, by the cnidoblasts and sensory cells. Their outer portions contain a layer of granules, which secrete the protective perisarc outside. The narrow

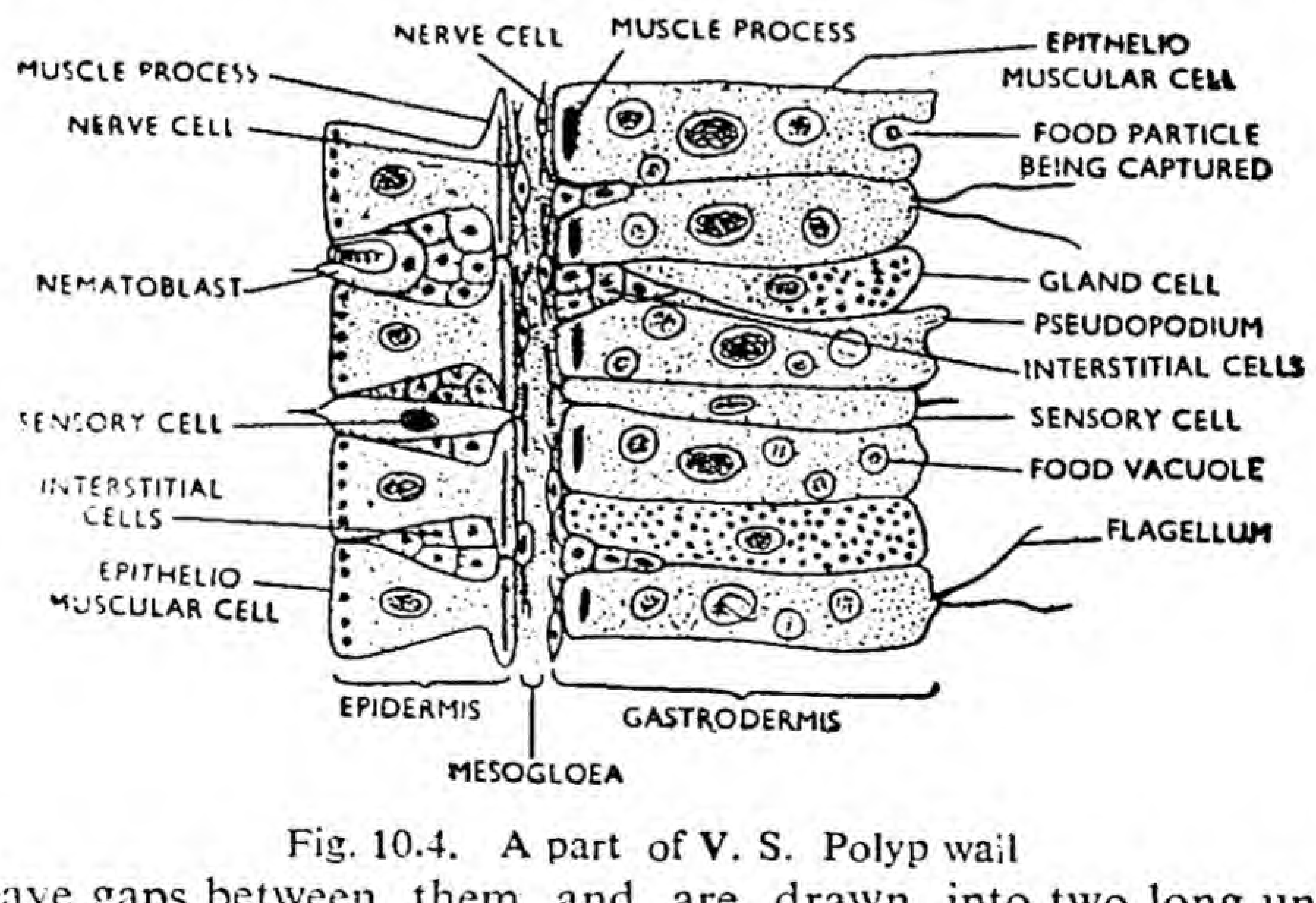


Fig. 10.4. A part of V. S. Polyp wall

ends leave gaps between them and are drawn into two long unstriped processes termed the **muscle-processes** or **muscle tails.** The latter contain contractile fibril, the **myoneme**, and lie against the mesogloea parallel to the body. They act as longitudinal muscles, which increase and decrease the body length by their coordinated extension and contraction respectively. The cell has alveolar cytoplasm and contains near its middle a nucleus with one or two nucleoli and a network of chromatin. It also possesses a few supporting fibrils called the **tonofibrils.**

(*b*) **Insterstitial Cells**. The interstitial cells occur in groups filling up the spaces between the inner narrow ends of the epithelio-muscular cells. They are small rounded cells, each with a relatively large nucleus containing one or two nucleoli. They arise early in development by the division of ectodermal and endodermal cells of the embryo. They are not specialised for any particular function. They can divide and transform themselves into other types of epidermal cells and take part in budding and reparative processes.

(*c*) **Nerve-cells**. The nerve cells are irregular in shape. Each consists of a small **cell body** with a nucleus and two or more fine branching processes, the **fibres**. The fibres of the adjacent nerve cells approach each other so closely that they appear to form a sort of nerve-net outside the mesogloea. The fibres may be in contact or intertwined round each other but there is no protoplasmic continuity between them. The nerve-net is, thus, not continuous. The nerve-net serves to transmit impulses from one part of the body to another.

(*d*) **Sensory Cells**. The sensory cells are scattered among epithelio muscular cells on the distal half of the polyp. They are long narrow cells, each provided at the free end with a fine flagellum arising from a kinetosome and prolonged at the other end into a thin nodulated fibre that meets the fibres from the nerve cells. The sensory cells are sensitive to external stimuli, like contact, light, temperature and chemicals.

(*e*) **Nematoblasts** or **Cnidoblasts**. These cells lie in the epidermis of the tentacles and hypostome. A nematoblast is a large pear shaped cell with its nucleus lying on one side (Fig. 10.5). It bears at its free end a small sensory bristle, the **cnidocil**, set in a slight projection. It develops in it a remarkable structure known as the **nematocyst**, probably composed of a chitin-like substance. The nematocyst consists of a large ovoid double-walled **capsule** and a long slender **thread-tube**. The thread tube is wide at the base. This part of the thread-tube is called the **butt**. It is about as long as the capsule itself and shows two regions : the proximal (one next to the capsule) wide **shaft** and the distal tapering **spinneret** bearing three large pointed **stylets** or **barbs** and a few spiral ridges with minute **spines**. When undischarged, the butt lies inverted in the capsule, the stylets and spines being on its inner surface and the thread-tube is coiled round it. The capsule is closed at its outer end by a flat lid or **operculum**. It is filled with a poisonous fluid, the **hypnotoxin**, which is a protein in nature. A number of short refractile rods lie on the outer surface of the capsule. They are connected with long contractile fibrils that pass to the base of the capsule. A thread, called **lasso**, arises from the base of the cnidoblast and is inserted on the capsule. It prevents the capsule from being thrown out at the time of discharge.

The nematocysts inject poisonous fluid in the body of the victim. Their thread tube can penetrate even the extremely firm chitinous covering of insects and crustaceans. The nematocysts do not have any connection with the nerve-cells or sensory cells. They are discharged by direct stimuli and, thus, function as independent effectors. The discharge is generally caused by a combination of mechanical

stimulation by the animals customarily used as food and chemical stimulation in the form of odours emanating from the proper food animals. This is indicated by the facts that touching the cnidocil

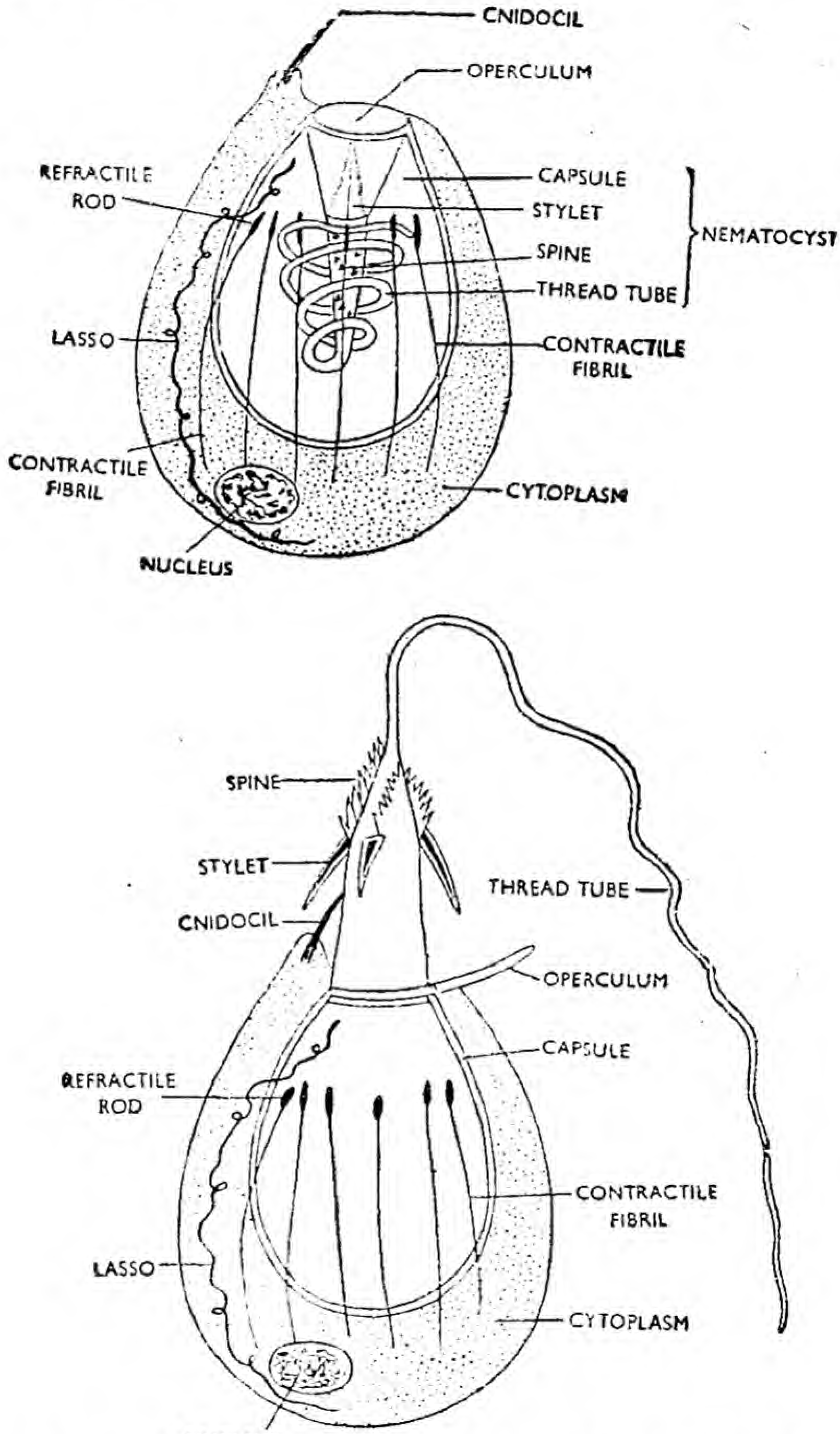


Fig. 10.5. Cnidoblast with penetrant type of nematccyst, undischarged above and discharged below.

with a glass rod or other objects does not result in the discharge of nematocysts.

On proper stimulation, the operculum of the nematocyst capsule opens and the thread tube quickly everts, *i.e.*, turns its inside out. In this operation, the base or butt, being continuous with the capsule wall, comes out first, and the rest then follows from base to tip. As the thread-tube everts the stylets and spines unfold to the outside. The tip of the thread-tube penetrates the body of the victim and hypnotoxin is injected into it. This paralyses or kills the victim.

Once discharged, the thread-tube cannot be withdrawn nor can another nematocyst be developed in the same cnidoblast. Such cnidoblasts migrate into the enteron, where they are digested.

2. **Gastrodermis.** The gastrodermis is primarily absorptive, digestive and muscular in function, though it also helps in the circulation of food. It comprises five types of cells : **epithelio-muscular** or **nutritive cells, gland cells, nerve-cells, sensory cells** and **interstitial cells.**

(*a*) **Epithelio-muscular Cells.** The epithelio-muscular cells form the major part of the gastrodermis. They are large columnar cells with a large nucleus having a distinct central chromatin nucleolus. Their outer ends are drawn out into **muscle-processes,** which contain fine contractile fibrils. These muscle-processes, unlike those of the similar cells of the epidermis, run at right angles to the body. They, thus, act as the circular muscles which cause variation in the thickness of the body by their expansion and contraction. The circular muscle-processes around the mouth act as sphincters to close this opening. The inner free ends of the epithelio-muscular cells may put out pseudopodia or flagella. The pseudopodia ingest solid food particles from the gastrovascular cavity for digestion in foodvacuoles within the cells. In this respect, they behave exactly like *Amoeba*. The flagella, by their lashing movements, keep the food circulating in the gastrovascular cavity. The epithelio-muscular cells also absorb food digested in the gastrovascular cavity and for this have conspicuous microvilli on their free border.

(*b*) **Gland Cells.** The gland cells are smaller than the epithelio-muscular cells among which they are scattered. They lack muscle processes and do not reach the mesogloea. They also bear one or two flagella. They are abundent in the body and the hypostome, but absent in the tentacles. Those in the hypostome secrete mucus for lubrication during ingestion of food, while those elsewhere secrete a digestive juice into the gastrovascular cavity.

(*c*) **Interstitial Cells.** The interstitial cells resemble those in the epidermis. They in fact migrate from the epidermis and

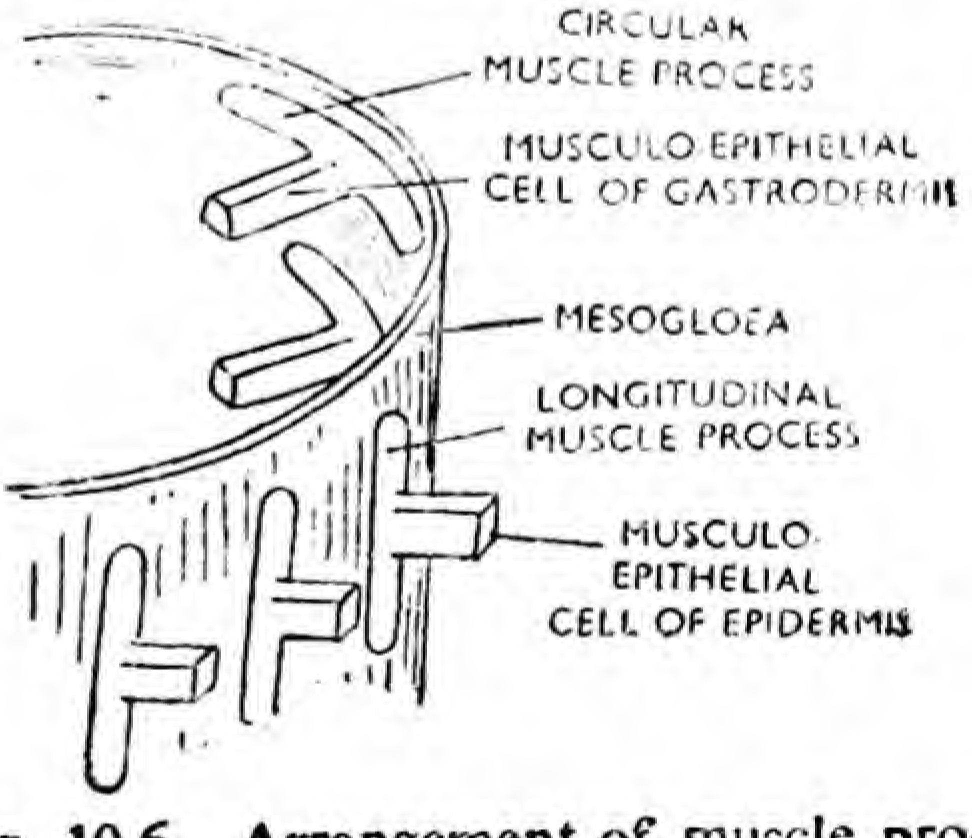


Fig. 10.6. Arrangement of muscle processes of the two layers of cells in the body-wall of the polyp.

lie in groups between the outer ends of epithelio-muscular cells. They develop into other types of cells when needed.

(*d*) **Nerve-Cells.** The nerve-cells also resemble their counterparts in the epidermis. They are, however, far less in number. They form the so called nerve-net inside the mesogloea. Perhaps the epidermal and gastrodermal nerve-nets are interconnected by fibres passing through the mesogloea.

(*e*) **Sensory Cells.** The sensory cells are fewer in the gastrodermis than in the epidermis.

3. **Mesogloea.** The mesogloea is a thin sheet of jelly-like material secreted by both epidermis and gastrodermis between them. It is traversed by nerve-fibres and contains no cells. Some migrating cells may be found in it at times. It serves as a basement membrane for the cells of both the layers. It also provides surface for the attachment of muscular processes and its elasticity helps in the extension of the body after contraction. It, thus, serves as a supporting layer or **skeleton.**

The tentacles are solid, having a core of a single row of large vacuolated gastrodermal cells.

Blastostyle. The blastostyles (Fig. 10.2) are developed when the hydrociulus has attained its full length. They are generally produced on the lower part of the colony in the axil of the branches that bear polyps. The blastostyle is a club-shaped zooid without mouth and tentacles. It is hollow and its cavity is continuous below with that in the rest of the colony. It is enclosed in a cylindrical expansion of the perisarc, the **gonotheca.**

The blastostyles serve to produce the third type of zooids, namely, **medusae.** This is done by budding (Fig. 10.9). The medusae ultimately get constricted off from the blastostyle and become free inside the gonotheca. The gonotheca, now, develops at its tip an aperture, the **gonopore,** and medusae escape into the sea through it. They are probably expelled through the gonopore by currents produced by rhythmic contractions of the polyps. Liberation of medusae occurs in spring or early summer.

A blastostyle with its gonotheca and the medusa buds is called the **gonangium** or **gonanth.**

Physiology

Nutrition. The polyps are the feeding zooids. They supply food to the entire colony. The food consists of small living organisms. They are captured with the help of nematocysts and brought to the mouth by tentacles as in *Hydra*. The annuli round the stalks of the polyps give them sufficient flexibility to move to and fro in water in pursuit of food. A part of the food is digested in the gastrovascular cavity of the polyp by the action of the digestive juices secreted by the gland cells of the gastrodermis. This is called **intercellular** or **extracellular digestion.** The partly digested food circulates in the gastrovascular cavity of entire colony by beating of the flagella of the gastrodermal cells and by

rhythmic contractions of the polyps. It is ingested from the gastrovascular cavity by the pseudopodia of the gastrodermal cells in which it is digested in much the same way as in *Amoeba*. This is known as the **intracellular digestion**. From the gastrodermis, some of the digested food is passed on to the epidermis by diffusion. The indigestible food is egested through the mouth of the polyp.

Respiration. Respiration is aerobic. It occurs through the general surface as in *Hydra*. The enteron of the entire colony contains water, which enters through the mouths of the polyps. This water is kept circulating by the contractions of the polyps and beating of gastrodermal flagella. The epidermis is also in contact with water, which diffuses through the permeable perisarc. Thus almost all the cells are in contact with water which has oxygen dissolved in it. This oxygen diffuses into the cells and the carbon dioxide likewise diffuses out of them.

Movements. Colony is incapable of locomotion. Its zooids, particularly the polyps, show local movements. They can contract and expand their body and can bend their tentacles.

Growth. Growth of the colony occurs more or less like a plant. It involves spreading of the branches of hydrorhiza along the substratum, development of new hydrocauli from the hydrorhiza and formation of new zooids on the branches arising from the hydrocauli. Until a polyp is developed at the top of a branch, the latter does not produce the next branch.

Excretion. Elimination of nitrogenous waste materials takes place by diffusion as in *Hydra*.

Behaviour. The polyps are sensitive to stimuli. They respond to touch and unfavourable chemicals by contraction.

The colony has no problem of osmoregulation as the sea-water is almost as dense as the cell contents. As the sea provides almost a uniform environment throughout the year and there is no desiccation, *Obelia* colony does not experience unfavourable periods and is capable of almost indefinite survival.

MEDUSA

Morphology

The medusae are set free in spring or early summer and take several months to become full grown. A mature medusa (Figs. 10.4 and 10.7) is a free-living, transparent, umbrella-like zooid, about six millimetres across. Its upper convex surface is called the **exumbrella** or **aboral surface** and the lower concave surface is called the **subumbrella** or **oral surface**. From the centre of the subumbrella, there hangs a vertical tube, the **manubrium**, at the tip of which lies four-sided aperture, the **mouth**. The edge of the umbrella projects inwards as a very narrow (almost rudimentary) shelf, the **velum**. Hanging down from the edge of the umbrella are numerous slender filaments, the **tentacles**. The tentacles are solid and their number, which is sixteen in the young medusa, increases with age. The four tentacles opposite the radial canals are called the **per-radial tentacles.** The four tentacles situated along the

bisectors of the angles between the radial canals are known as the **inter-radial tentacles.** The eight tentacles occupying the radii between the per-radial and inter-radial tentacles are termed the **ad-radial tentacles.** The eight ad-radial tentacles bear sense organs at their bases. The bases of all the tentacles are slightly swollen.

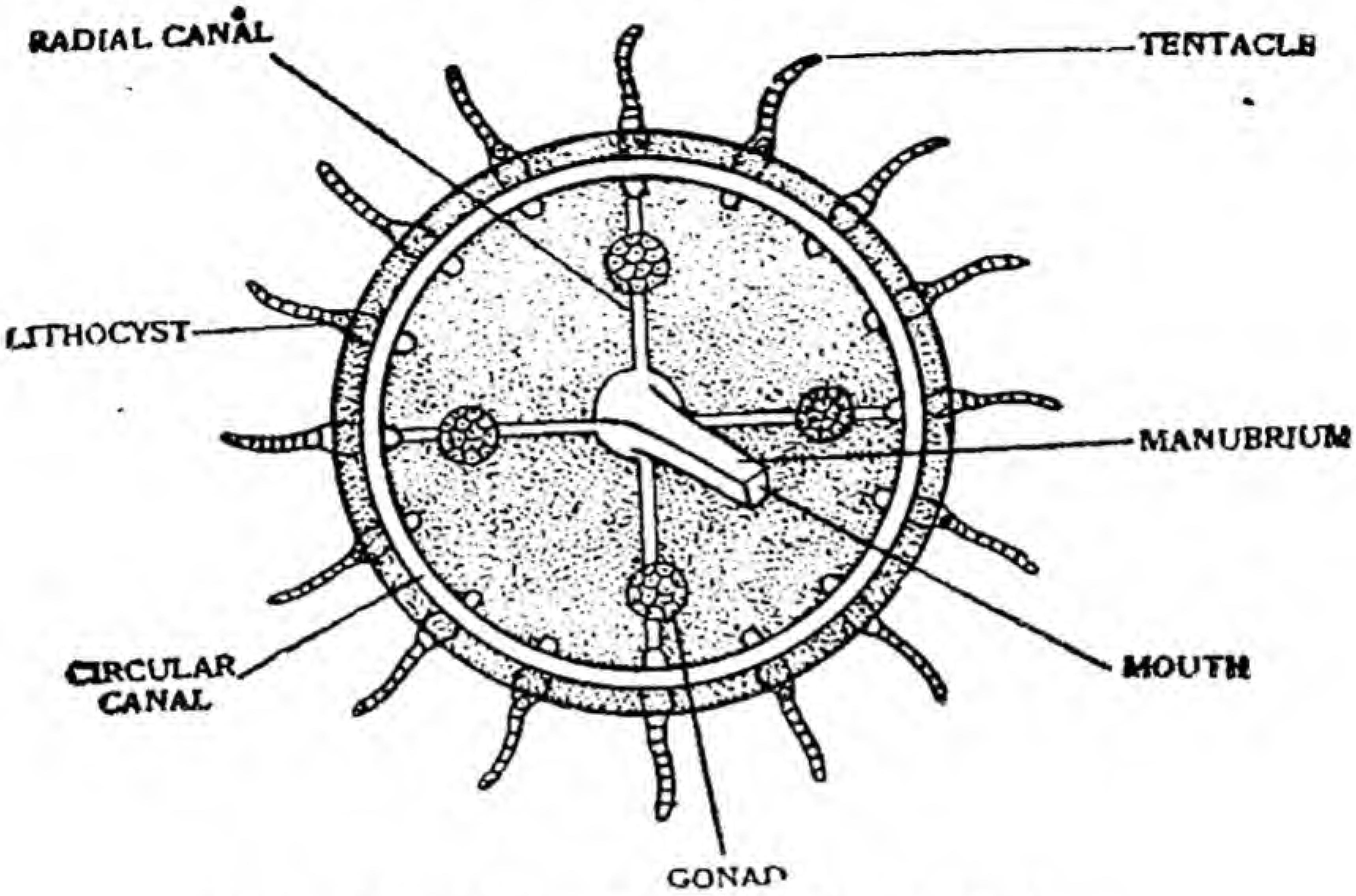


Fig. 10.7. Medusa of *Obelia* (oral view)

The mouth opens into a short cavity, the **gullet,** which traverses the manubrium. The gullet leads above into a small **stomach.** From the stomach start four **radial canals,** which run towards the margin of the umbrella at equal distances from each other. At their distal ends, the radial canals open into a **circular canal** running round the umbrella. The gullet, stomach, radial canals and circular canal form the **gastro-vascular cavity** for the digestion and distribution of food.

Histology

The outer surface of all the parts of the **medusa,** namely, the ex-umbrella, subumbrella, manubrium, velum, and tentacles, is covered with a continuous layer of epidermis (Figs. 10.8 and 10.9). The whole of the gastrovascular cavity is lined with gastrodermis. The gastrodermis forms a thin sheet, the **gastrodermal lamella,** between the radial canals and a thick **core** in the tantacles. A noncellular gelatinous **mesogloea** is present everywhere between the epidermis and gastrodermis. The **velum,** however, contains mesogloea between two layers of epidermis, there being no gastrodermis in it. The mesogloea is thicker on the exumbrellar than on the subumbrellar side. The tentacles have numerous stinging cells in their epidermis. The stinging cells occur round the mouth also. They are not found anywhere else. There are aggregations of interstitial cells in the swollen bases of tentacles. These cells form a reserve stock to replace the discharged cnidoblasts.

The musculature is better developed and more efficient than in the polyp. The muscle processes of the epitheliomuscular cells are very

strong, particularly on the subumbrellar side. On this side, along certain tracts, one circular and a few radial, the muscle processes are longer than the cell itself and have separate nuclei so as to form a sort of separate muscular tissue.

The nervous system is also superior to that of the polyp. It includes the sense organs and a double nerve-ring in addition to the double nerve-net in the layers of the body.

The **sense organs** are concerned with equilibrium and are called the **statocysts**. They are eight in number and lie at the bases of the adradial tentacles on the subumbrellar side. Each statocyst is a small fluid-filled sac (Fig. 10.8). Its walls consist of a single layer of epidermal cells, which are sensory near the margin of the medusa. A large cell hangs in the sac from its roof. This cell is called the statolith **cell** and contains a self-secreted calcareous particle called the **statolith.** Outside the statolith a fringe of sensory protoplasmic processes hangs from the sensory cells of the sac. When the medusa floats horizontally, the statoliths remain vertical and do not touch the sensory processes. When the medusa is inclined in any direction, the statoliths of that side touch the sensory processes and stimulate them. The nerve-impulse, thus set up, is transmitted by nerve-cells to the muscle-processes which contract to restore the equilibrium.

The nerve-rings are formed by concentration of nerve cells, one outside the circular canal and one just inside it. Both the nerve-rings

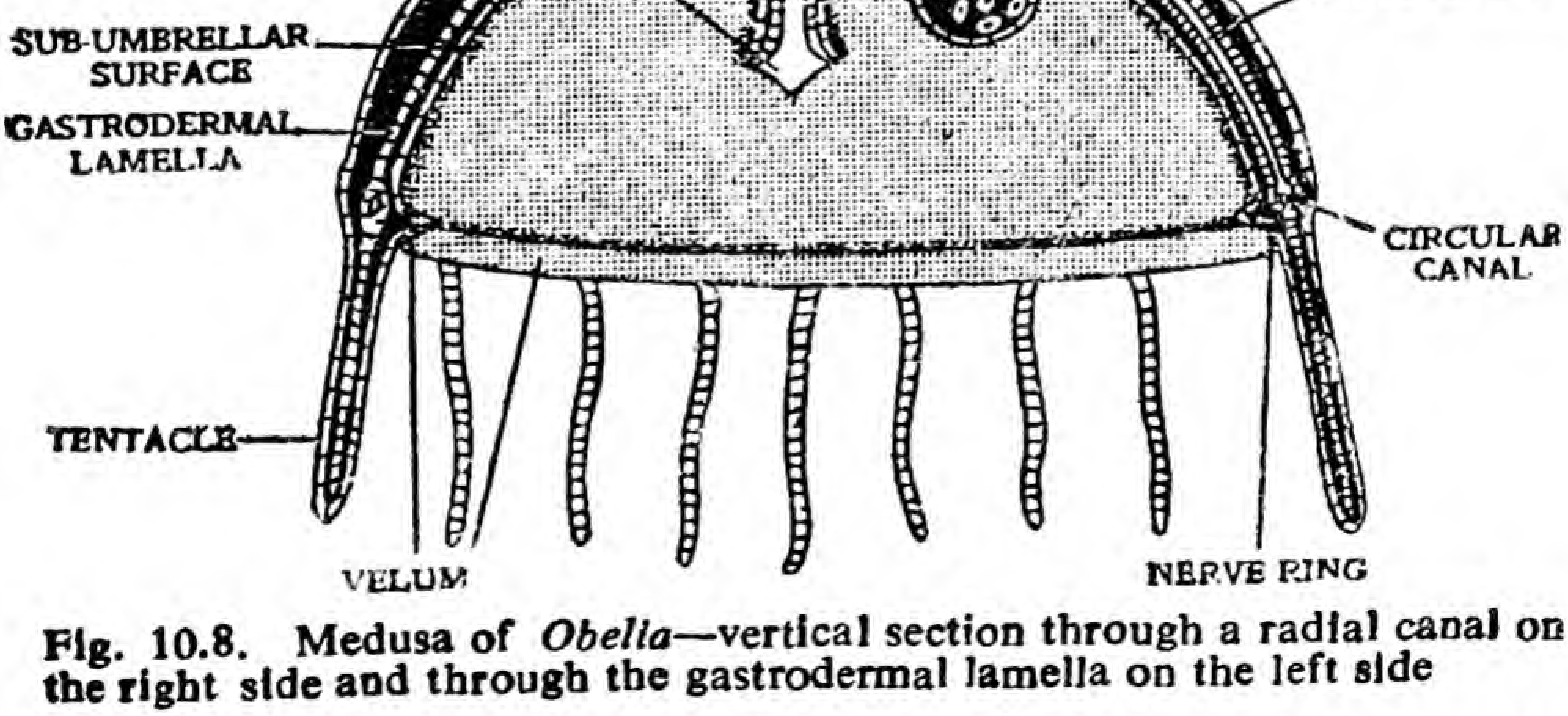


Fig. 10.8. Medusa of *Obelia*—vertical section through a radial canal on the right side and through the gastrodermal lamella on the left side

are connected with the nerve-nets by nerve-fibres. The outer nerve ring receives impulses from the statocysts by nerve-fibres and relays them to

the inner nerve-ring, which transmits them to the subumbrellar muscle processes. The latter then contract in response.

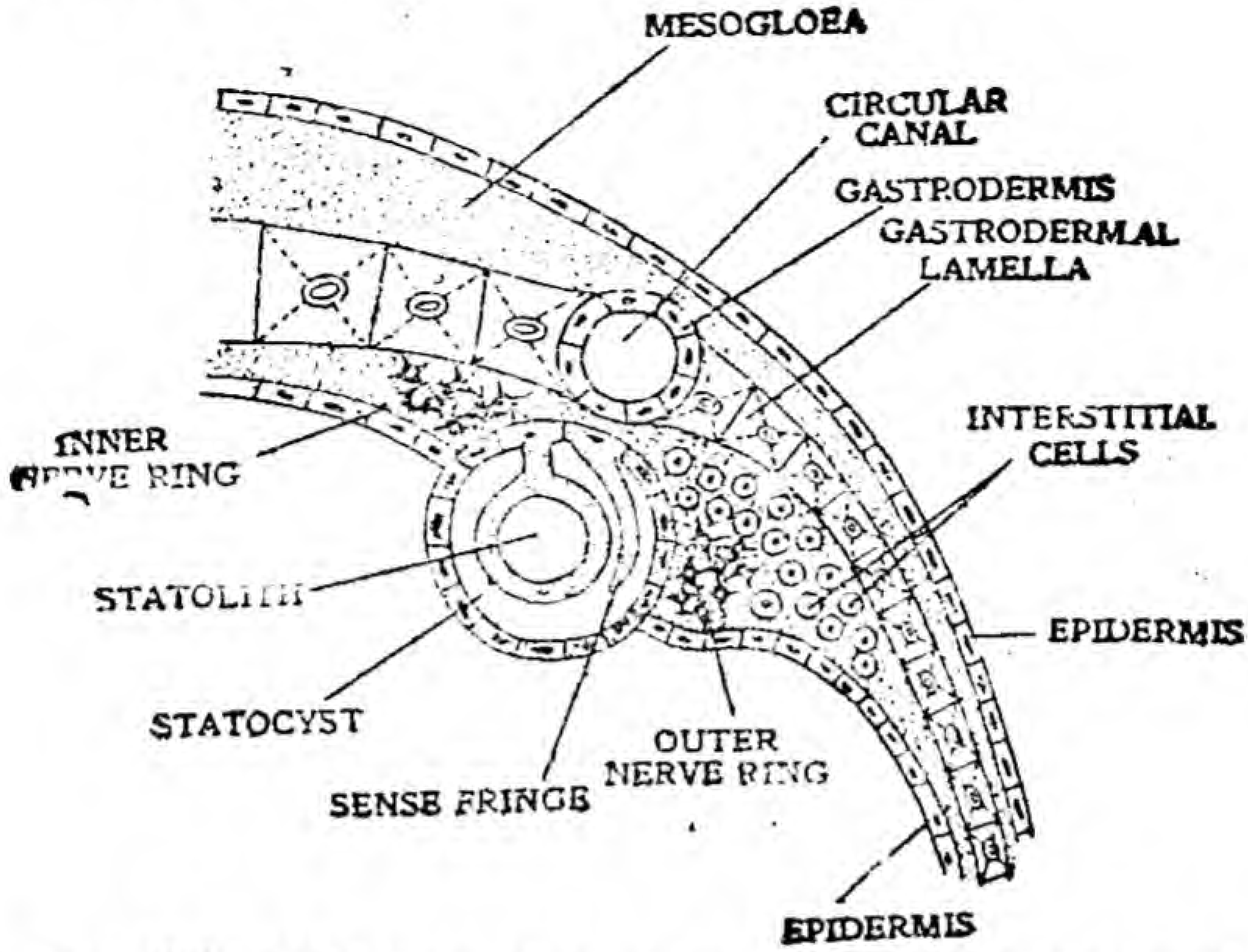


Fig. 10.9. V.S. through the base of an ad-radial tentacle

Origin (Fig. 10.10)

As already stated, the medusae develop from the blastostyles. **Each** medusae initiates its development as a small outgrowth, the **medusae bud,**

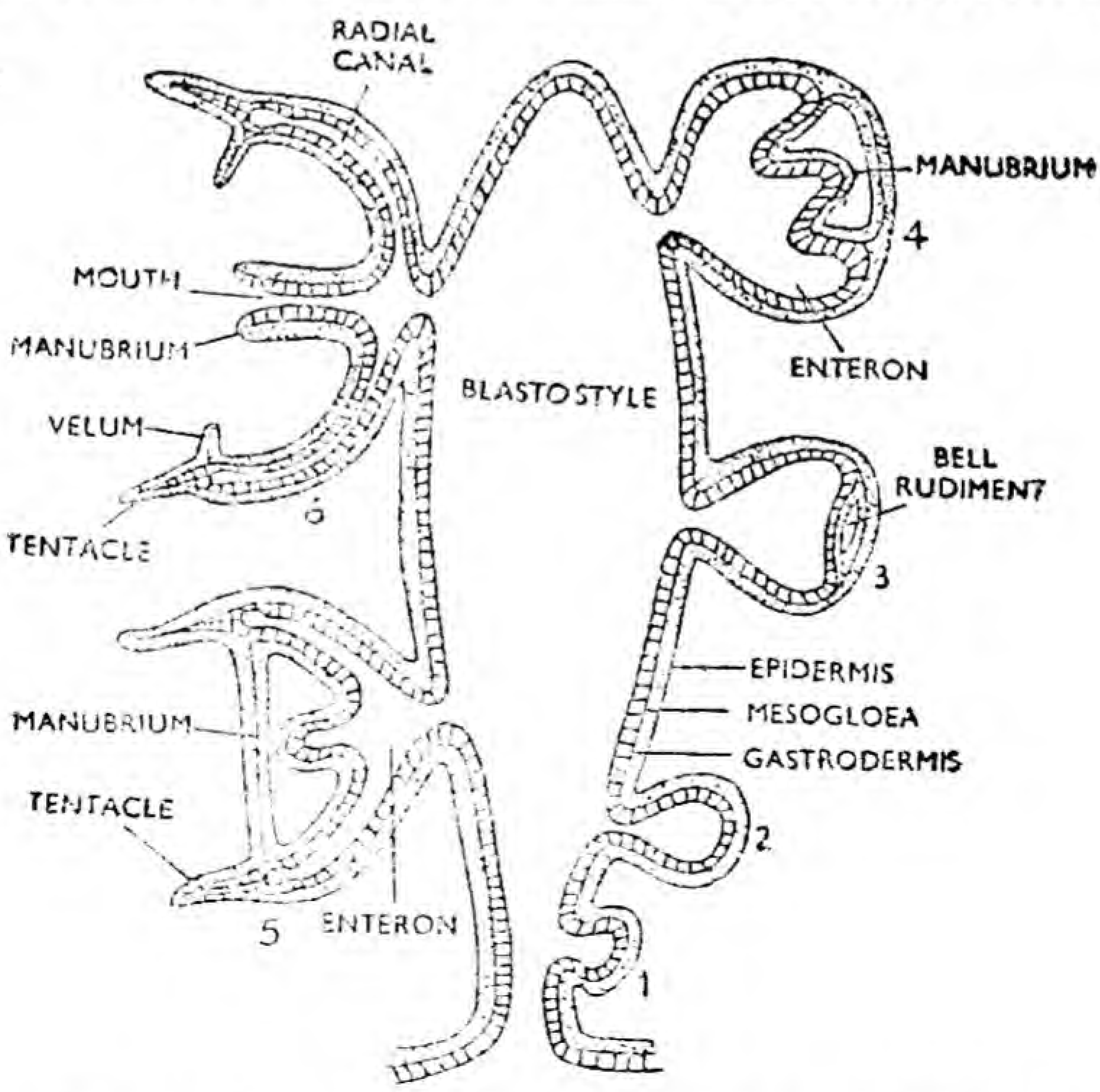


Fig. 10.10. Origin of medusae on the blastostyle

from the wall of the blastostyle. The bud enlarges and becomes almost spherical. It encloses an extension of the gastrovascular cavity of the blastostyle and its wall consists of three layers : epidermis, mesogloea and gastrodermis, which are continuous with the corresponding layers of the blastostyle. The epidermis at the distal end of the bud produces, by cell division, a disc of cells on its inner side. By further cell division the disc becomes two layered. Later a small cavity appears between the two layers of the disc. The cavity enlarges as the bud grows and is destined to become the sub umbrellar cavity. The outer wall of the cavity consists of two layers of epidermis, while the inner wall is composed of epidermis, mesogloea and gastrodermis. From the inner wall of the cavity pushes out a blunt projection which later forms the manubrium. Out-pushings around the manubrium mark the beginning of the radial canals. The margins of the bud grow out to initiate the formation of tentacles. The outer wall of the bud breaks down, leaving a small part of it at the periphery as the velum. The manubrium elongates and gets perforated by mouth at its free tip. The connection of the bud with the blastostyle is then severed by constriction. The aperture formed by severing of connection closes up soon. This makes the medusa free. It is to be noted that the attached end of the medusa bud becomes the exumbrellar surface.

Physiology

Nutrition. Food consists of small organisms. They are captured with nematocysts present on the tentacles. Ingestion is assisted by folding inwards of the margin of the bell. Both intercellular and intracelluar digestions occur. Egestion takes place through the mouth.

Locomotion. Medusa generally floats passively and is drifted away by water currents. It can, however, swim actively by rhythmic contractions of its body. With these contractions water is forced out of the umbrella in one direction and the medusa is propelled in the opposite direction. The tiny medusa has been using this principle of jet propulsion for millions of years before man employed it in the aircraft. Contraction of the medusa is brought about by the contraction of strongly developed epidermal muscle-processes of the subumbrellar side described above in histology. Expansion of the medusa is caused chiefly by the elastic mesogloea regaining its shape and partly by the contraction of muscle processes in the middle of the exumbrellar surface.

Respiration and Excretion. Medusa lacks special organs for respiration and excretion. Oxygen is absorbed from the surrounding water and carbon dioxide and waste materials are eliminated from the body through the general surface of the epidermis and gastrodermis.

Growth. Medusa grows in size by the division of all of its cells, except the nerve-cells. New tentacles arise as small buds at the margin.

Coordination Medusa possesses an efficient arrangement for the reception of stimuli and transmission of impulses. This is very essential for maintaining equilibrium and causing locomotion. This is brought about by the cooperation of sense organs, nerve-rings, nerve-nets and muscle-processes already described.

Reproduction. The medusae are the **sexual zooids.** The sexes are separate. Each medusa, when mature, develops four **gonads** on the subumbrellar side in the middle of the radial canals. **A gonad** is an ovoid sac which consists of an outer wall of epidermis continuous with that of the subumbrella, an inner wall of gastrodermis continuous with that of the radial canal, and an intermediate mass of sex-cells, **ova** or **sperms** (Fig. 10.8). The sex cells are derived from the epidermis. On maturity, the sex cells are shed into the surrounding water by rupturing of the outer wall of the gonads. Fertilization occurs in water. The medusa dies after liberating its gametes.

Development. The zygote undergoes holoblastic segmentation. This produces a hollow spherical embryo, the **blastula** (Fig. 10.10). The cavity of the blastula is called the **blastocoel.** The wall of the blastocoel consists of a single layer of cells, the **blastomeres**. The blastomeres cut off from their inner surface new cells which drop into and fill up the blastocoel. The embryo is now called the **solid gastrula** or **stereogastrula.** The outer layer of cells is now termed the **ectoderm** and the inner mass of cells the **endoderm**. The gastrula elongates and its ectodermal cells acquire cilia. It is then known as the **planula**. The planula swims freely in water with its cilia, keeping its broad anterior end in front. During the period of its free existence, the solid endoderm develops a cavity, the **enteron,** by a split in it. With the result, the larva becomes truly two-layered. Some cellular differentiation occurs in both the layers. Ectoderm develops sensory cells and cnidoblasts and the endoderm starts developing gland cells. The planula now settles down and attaches itself to some object by its anterior end. The cilia disappear. The attached end flattens into a disc from which later hydrorhiza grow out by budding. The free end broadens and develops tentacles by evagination. Mouth appears amidst the tentacles. Cellular differentiation proceeds further and the ectoderm and endoderm assume the characteristics of epidermis and gastrodermis respectively. This stage looks like *Hydra* and is termed the **hydrula**. The hydrula develops a perisarc, which is secreted by its epidermis. It grows a stalk which raises it upwards. This stalk by budding forms a hydrocaulus. This inaugurates formation of a colony.

Alternation of Generations

Alternation of generations is the phenomenon in which an organism exists in two distinct forms, the **asexual** and the **sexual**, and the two alternate regularly in the life-history ; the asexual generation giving rise by asexual means to the sexual generation which then, in turn, by sexual method produces the asexual generation.

Obelia seems to illustrate this phenomenon. The colony of this animal begins as a single zooid. As it grows, it forms new zooids, namely, polyps, blastostyles and medusae, by budding. Since budding is an asexual method of multiplication, the colony may be said to represent the asexual generation. The medusae, on becoming free from the colony, bear gonads which shed gametes The latter, by fertilization, form the zygote which, by segmentation, develops into a polyp that grows into a new colony. As the new colony results by a sexual process from

the medusae, the latter may be said to represent the sexual generation. The medusae never give rise to another generation of medusae. They

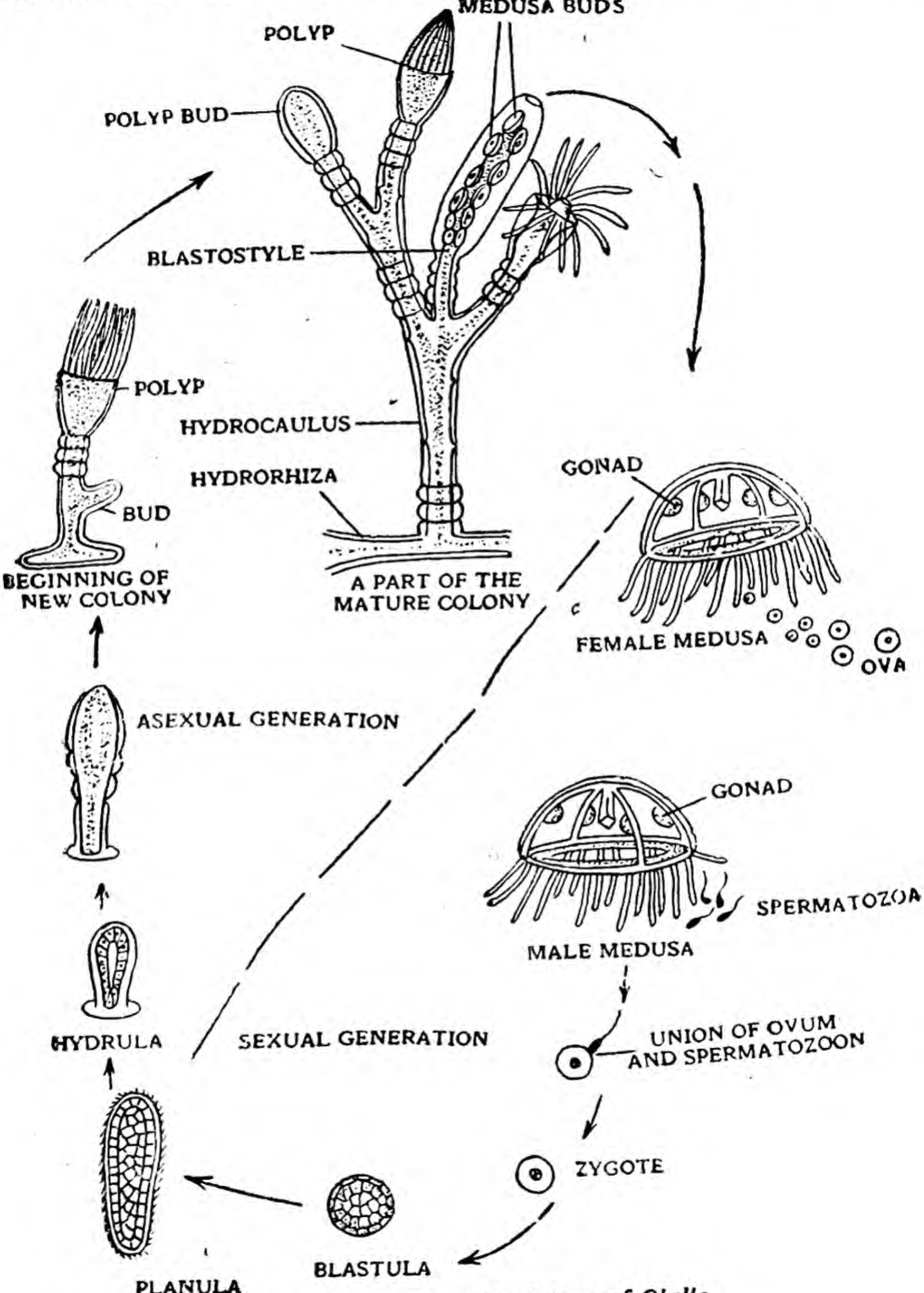


Fig. 10.11. Life-history of *Obelia*

always produce a colony by sexual method. The colony is, likewise, incapable of founding another colony at a new site. It always forms medusae and other zooids by budding. The asexual generation or the colony, thus, regularly alternates with the sexual generation or medusae.

It has been recently found that the gametes are not produced in the gonads of the medusa. They actually start their differentiation in the epidermis of the blastostyle and later migrate into the medusa during its development from the blastostyle. Under these circumstances, it is rather impossible to distinguish between the sexual and the asexual generations.

Moreover, the term "alternation of generations" truly applies only to plants, notably the Bryophyta and the Pteridophyta. In these plants, the haploid sexual generation, called the **gametophyte**, produces gametes which by fertilization give rise to the diploid asexual generation called the **sporophyte**. The latter produces the spores which grow into the gametophyte. In *Obelia*, the apparent asexual and sexual generations, namely, the colony and the medusae respectively, are both diploid, the haploid phase being only represented by the gametes.

The facts given in the two preceding paras show that there is no alternation between the sexual and the asexual generations in *Obelia*. It, however, possesses alternation between the fixed and the free-swimming generations. This brings about dispersal and prevents overcrowding of the species. The fixed colony in due course of time exhausts oxygen and food from its immediate surroundings which, thus, become unfavourable for healthy growth. The locomotory medusae swim away from the unfavourable site of the parent colony and establish new colonies where conditions of life are more appropriate.

Since the colony of *Obelia* does not develop gonads, it may be regarded as the **juvenile** stage and the medusae which produce gonads as the adults. Therefore, instead of describing the phenomenon that occurs in *Obelia* as the "alternation of generations", it is better to term it **metagenesis**, meaning deferment of the power of sexual reproduction.

Polyp Versus Medusa

1. **Resemblance**. Apparently there seems to be no similarity between the polyp and the medusa. Actually, however, the two are homologous structures, being built on the same fundamental plan. Resemblance between the two is so close that the one can be easily derived from the other (Fig. 10.12). An inverted polyp at once assumes the medusoid form if its region of tentacles is pulled out and the manubrium is pushed up. This, together with the thickening of mesogloea, especially on the upper side, brings the walls of the polyp together so that they meet everywhere to form the **gastrodermal lamella**, except along the radial and circular canals. Thus, we find that the polyp and the medusa have the same layers which occupy the same relative positions in both, the epidermis covering the outer surface, the gastrodermis lining the cavities and the mesogloea lying between the two. In both, the gastrovascular cavity has a single outlet and both have solid tentacles bearing cnidoblasts. The nature of food and modes of capturing and digesting it are also similar in the two. Finally, both arise as buds on the colony and show radial symmetry.

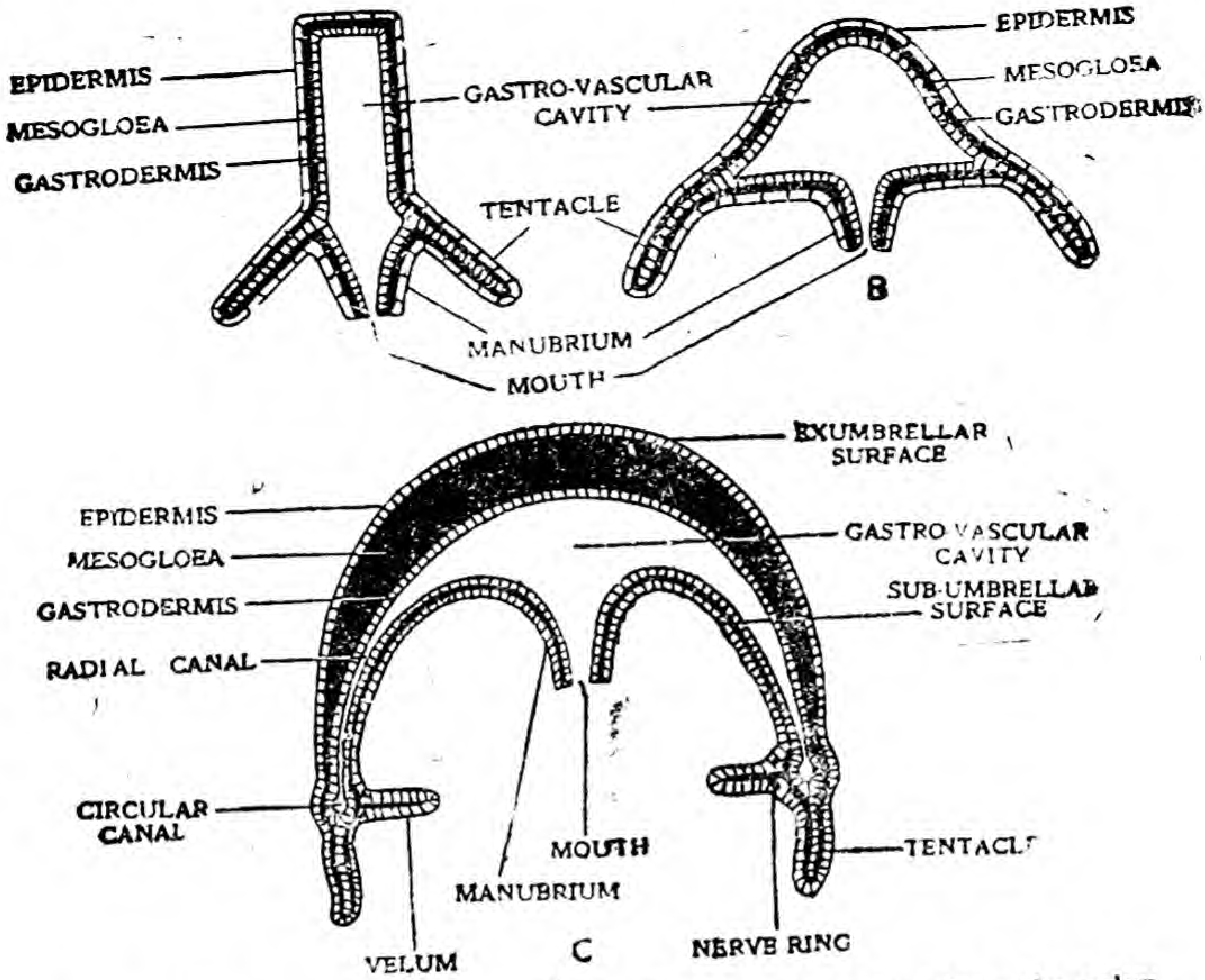


Fig. 10.12. Stages showing the derivation of the medusa from the polyp

2. **Difference.** Though basically alike, the polyp and the medusa have developed several differences in order to perform different functions. The more important differences are tabulated below.

TABLE 5.

Polyp	Medusa
1. Body of the polyp is long and cylindrical.	1. Body of the medusa is short and umbrella-like.
2. Polyp is a fixed zooid.	2. Medusa is a free-living zooid inthe mature stage.
3. Polyp is enclosed in a transparent protective covering, the hydrotheca.	3. Medusa is without any covering.
4. The mouth of the polyp is circular and lies at the upper end of the upright manubrium.	4. The mouth of the medusa is four-sided and lies at the lower end of the hanging manubrium.
5. The tentacles of the polyp are situated at the baseof the manubrium.	5. The tentacles of the medusa are situated at the margin of the umbrella.
6. The tentacles are about 30 in number.	6. The tentacles are 16 in the young stage, but number increases with age.
7. The gastrovascular cavity is a single spacious cavity occupying the whole of the body of the polyp.	7. The gastrovascular cavity is restricted and differentiated into the gullet, stomach, radial canals and a circular canal.

Contd.

Polyp	Medusa
8. There is no endoderm lamella.	8. There is endoderm lamella between radial canals in each quadrant.
9. The mesogloea, is almost of uniform thickness throughout.	9. The mesogloea is much thicker on the exumbrellar side than on the other side.
10. The nervous system is poorly developed, consisting only of nerve-nets.	10. The nervous system is much better developed, consisting of a double nerve-ring and a double nerve-net.
11. There are no sense organs.	11. There are eight sense organs, the statocysts.
12. The polyp feeds and protects the colony.	12. The medusa brings about sexual reproduction and dispersal of the colony.
13. Polyps are produced directly on the hydrocauli.	13. Medusae are produced on the blastostyles and not directly on the hydrocauli.
14. Polyp lacks gonads.	14. Medusa bears 4 gonads
15. Polyp belongs to the asexual generation.	15. Medusa belongs to the sexual generation.

3. **Advancement.** Medusa shows a distinct morphological advancement over the polyp in having sense organs and two nerve-rings in the nervous system ; almost an independent muscular tissue ; differentiation of gastrovascular cavity into the gullet, stomach, radial canals and circular canal ; gonads for sexual reproduction ; and free-swimming life.

Morphological and Physiological Differentiation

Obelia shows morphological and physiological differentiation to a greater extent than *Hydra*. It is a colonial animal with three types of individuals or zooids. The horizontal branches of the colony fix it to the substratum, the polyps feed and defend the colony, the blastostyles bud off medusae which bring about sexual reproduction and dispersal, the perisarc, hydrotheca and gonotheca are protective and skeletal in function, and so on. Some of the cellular elements are also more elaborate in *Obelia*, at least over certain parts. For instance, in medusa along certain tracts, one circular and a few radial, on the subumbrellar side, the muscle-processes are larger than the cells and have separate nuclei so as to form a separate muscular tissue. Again, the medusa has sense organs and a double nerve-ring in addition to the nerve net. This increase in the differentiation of structure and function is maintained in the succeeding animals.

Adaptations to Environment

Flexibility provided by the annuli present round the stalks of the polyps and the extensile nature of the tentacles enable the polyps to hunt for the prey over a large area around them and thus compensate for the fixed mode of life. Intracellular digestion enables it to make full use of the captured food in the absence of sufficient concentration of digestive juices in the gastrovascular cavity due to its communication with the

outside water. Thin body-wall facilitates respiration and excretion by diffusion. Ability to keep off the enemies with the help of nematocysts and protection afforded by the perisarc contribute to the survival of the colony. Production of free swimming medusae carries on dispersal, so essential for a fixed creature.

Classification

The sea-fir described here belongs to the

Phylum :	**Coelenterata**	Because of being diploblastic, having cnidoblasts and containing coelenteron with a single outlet.
Class :	**Hydrozoa**	Due to the possession of ectodermal gonads and regular alternation of fixed hydroid and free swimming medusoid phases.
Family :	**Campanulariidae**	Because of having cup-like hydrothecae at the ends of distinct branches.
Genus :	*Obelia*	Because the reproductive zooids are free-swimming medusae.
Species :	*geniculata*	Because of being colourless and about 30 mm. tall.

TEST QUESTIONS

1. What is alternation of generations ? Illustrate this phenomenon from the life-history of *Obelia*.

2. Define the following terms. Give at least two examples in each case. Polymorphism, Colonial animal, Division of Labour, Diploblastic and Triploblastic Animals, Metazoa, Sedentary Animal.

3. What is meant by physiological and morphological differentiation in Metazoa? Explain it fully with reference to *Obelia* colony.

4. Name any colonial animal you have studied. Describe the various types of zooids found in this animal, giving functions of each.

5. Give an account of the histological structure of the polyp of *Obelia*.

6. Describe the medusa of *Obelia*. How does it differ from the polyp. ?

7. Why is the colony of *Obelia* called trimorphic ? What is the habitat of this colony ? How does dispersal occur in *Obelia* colony and what purpose does it serve ?

8. Write notes on the following :
   (*a*) Locomotion in the medusa of *Obelia*,
   (*b*) Modes of feeding and digestion in the polyp of *Obelia*,
   (*c*) Nematocysts,
   (*d*) Perisarc.

CHAPTER 11

Pheretima posthuma

(The Earthworm)

There are about 1,500 species of earthworms, varying in size from less than 1 mm. to 2 metres. They are found all over the world, except the arctic and antarctic regions. The common Indian species is *Pheretima posthuma*. It is studied as a type because it forms a good representative of the phylum Annelida, is easily available, has a convenient size and is perfectly harmless.

Natural History

Habitat. The earthworms live in the moist earth rich in dead organic matter or humus. Old pastures, lawns and gardens are the places where they are met with in abundance. According to Henson, there are, on an average, about 53,000 earthworms in an acre of garden soil. They are rare or absent in the poor, acidic, sandy or dry soils. The earthworms have selected rich moist earth as their habitat for various reasons. They respire through the skin, which the wet soil keeps moist for the diffusion of gases. The dead organic matter of the soil forms their chief food. Moisture and humus make the earth soft for burrowing.

Habits. The earthworm is a nocturnal animal. During the daytime it lies passive in the burrow with the anterior end facing upwards. At night it becomes active and either comes out of burrow completely to roam about or keeps the hind end fixed in the burrow and slowly moves the rest of the body round and round. The earthworms emerge from their burrows during the daytime only if their burrows are flooded with rain. This is the basis for the old belief that the earthworms come down with rain. They actually come up with rain.

Burrowing. The earthworm makes its burrow by simply pushing the body through the soil if it is soft and by eating the soil if it is hard. The burrow runs almost vertically into the earth and usually extends to a depth of 30 to 60 centimetres. During the dry periods of the year, *i.e.* spring and summer, the worm descends much deeper (180 to 210 centimetres) in search of moisture, whereas in the rainy season, when the burrow gets flooded with water, it comes out on the surface. After deserting one burrow, the worm makes a fresh one. The entrance to the burrow is often covered with faecal castings, small pebbles or leaves to keep out water and enemies. The bottom of the burrow is comparatively large for enabling the worm to turn about. The walls of the

burrow may be lined with bits of dead leaves, faeces of the worm or slime secreted by the skin glands.

Feeding. The food of earthworm mainly consists of dead organic matter present in the soil. The worm takes its food along with the soil by a sucking action. The organic matter is digested and absorbed in the alimentary canal and the residue eliminated from the anus on the surface of the ground in the form of the familiar "**worm castings**". The latter are a matter of common observation as small heaps in the fields and gardens during the rainy season.

The earthworm also feeds directly on the bits of leaves and green algae growing on the stones and moist earth.

Breeding. The earthworm is **hermaphrodite** or **monoecious**, *i.e.* the same individual has organs of both the sexes. Self-fertilization is, however, not possible. Copulation takes place between two worms and involves the mutual exchange of spermatozoa. It occurs at night or early in the morning before sunrise during the warm moist climate prevailing from July to October. The animal is **oviparous**. Several eggs and spermatozoa are packed in an egg-case or **ootheca** which is deposited just beneath the surface of the ground. Only one worm develops in an ootheca. The young worm resembles the adult.

Regeneration. Earthworm possesses a good power of regeneration. If it happens to be cut into halves in the soil by agricultural implements, it does not necessarily die. Each half may develop the missing portion and grow into a new worm.

Grafting. Grafting is fairly easy in the earthworm. A very small worm can be formed by cutting away from its middle a piece of several centimetres and grafting the two ends together. Strange two-headed or two-tailed worms can be formed by grafting together the appropriate parts of several worms. Such monsters, however, die after some time due to lack of feeding and defaecation.

Enemies. The earthworms fall a prey to several enemies. Frogs, toads and hedgehogs capture them when they are roaming about on the ground ; certain birds drag them from the burrows and centipedes and moles attack them underground.

External Characters (Figs. 11.1 to 11.4)

Form, Size and Colour. The earthworm shows bilateral symmetry. It has long, narrow, cylindrical body with a pointed anterior and a rounded posterior end. An adult worm measures about 150 millimetres in length and 3 to 5 millimetres in thickness. The maximum thickness of the body is a little behind the anterior end. The living worm is deep-brown in colour, the dorsal surface being a bit darker than the ventral. The dorsal surface is further distinguished by a dark median line running along the body.

Segmentation. The whole surface of the body is marked by circular grooves or **annuli**, which divide it into distinct segments or **metameres.** The segments vary from 100 to 120 in number. Within each annulus

there is, as a rule, a vertical partition or **septum**, which divides the body internally into compartments. We, thus, find that the external segmentation of the body by annuli largely corresponds to the internal segmentation by septa. This is called **metameric segmentation.**

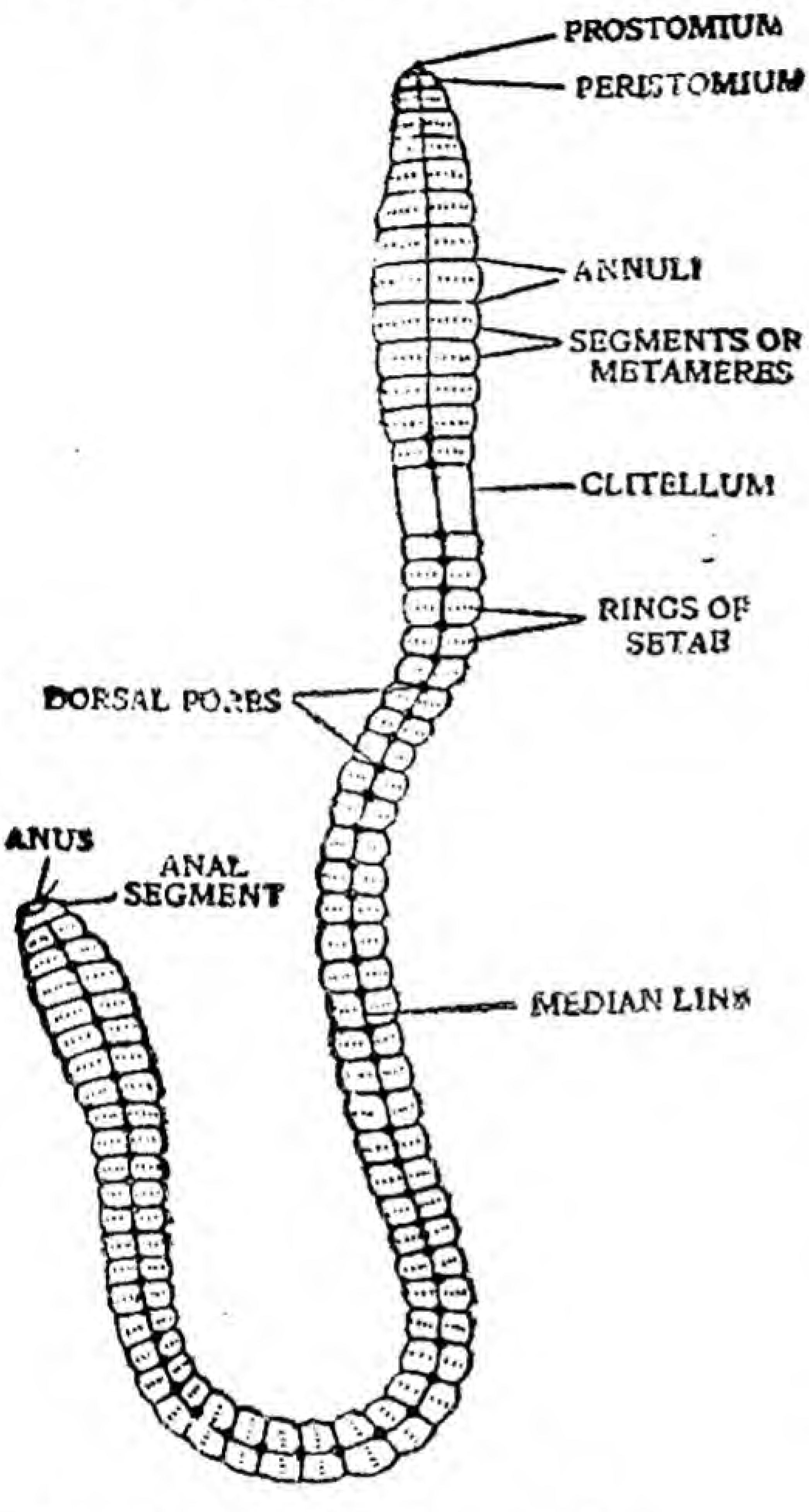


Fig. 11.1. *Pheretima posthuma* (dorsal view)

Clitellum. A prominent band encircles the fourteenth, fifteenth and sixteenth segments. This is known as the **clitellum** or, to be more appropriate, the **cingulum.** As we shall learn later, the clitellum is glandular in nature and serves to secrete the material for the formation of the egg-case. The clitellum divides the body of the worm into three regions : the **pre-clitellar,** the **clitellar,** and the **post-clitellar.**

Setae. Each segment, except the first and the last, bears in its middle, a ring of small, f-shaped, chitinous bristles, the **setae** or **chaetae.** The setae of the clitellar segments are lost in the full-grown worms. The setae help the animal in locomotion and are of special service to it in climbing out of a burrow. When pulled by an enemy from the burrow, the worm extends its setae and acquires firm attachment with the wall of the burrow.

Apertures. The body of the earthworm has a number of apertures. These include :—

(*i*) **Mouth.** It is a crescentic aperture at the anterior face of the first segment known as the **peristomium.** The dorsal edge of the peristomium projects forwards above the mouth as a small fleshly lobe, the **prostomium.**

(*ii*) **Anus.** It is a slit-like aperture at the posterior face of the last or anal segment. There is, thus, no tail in earthworm like other invertebrates.

(*iii*) **Female Genital Pore.** It is a minute median aperture lying on the ventral side of the fourteenth segment.

(*iv*) **Male Genital Pores.** These are a pair of small apertures situated on small papillae present on the ventral side of the eighteenth segment. In line with the male genital pores, the seventeenth and nineteenth segments bear a pair of papillae each. These are called the **genital or copulatory papillae.** Each genital papilla has a shallow pit which looks like an aperture.

(v) Spermathecal pores. These are four pairs of small elliptical apertures situated ventrolaterally in the grooves between the fifth and sixth, sixth and seventh, seventh and eighth, and eighth and ninth segments.

(vi) Dorsal pores. These are minute holes present along the mid-dorsal line in the intersegmental grooves. The first dorsal pore is found in the groove between the twelfth and thirteenth segments. This is followed by a pore in each succeeding groove except the last. The dorsal pores connect the coelom with the exterior.

Fig. 11.2. Seta

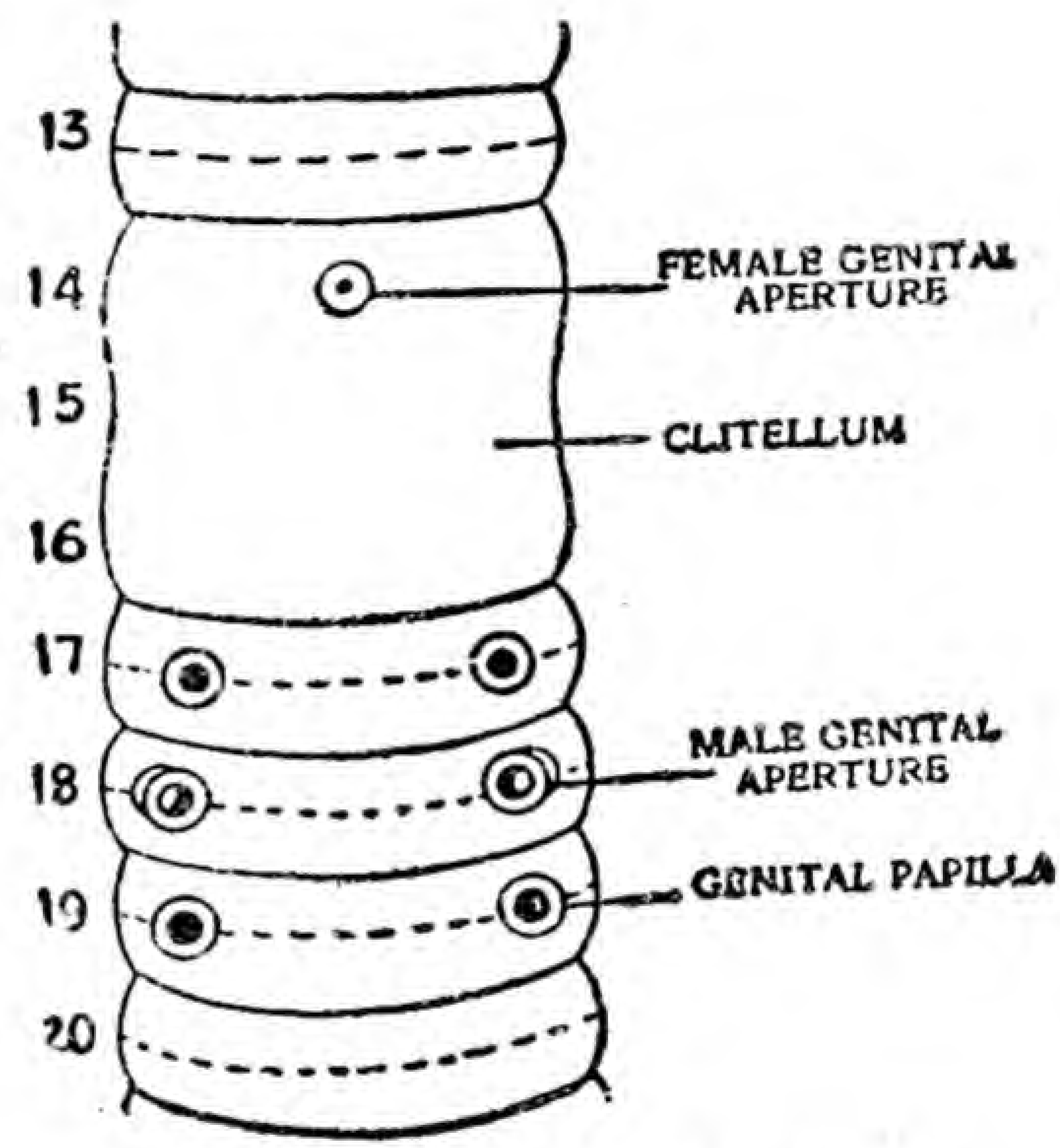


Fig. 11.3. *Pheretima.* The genital area in the ventral view

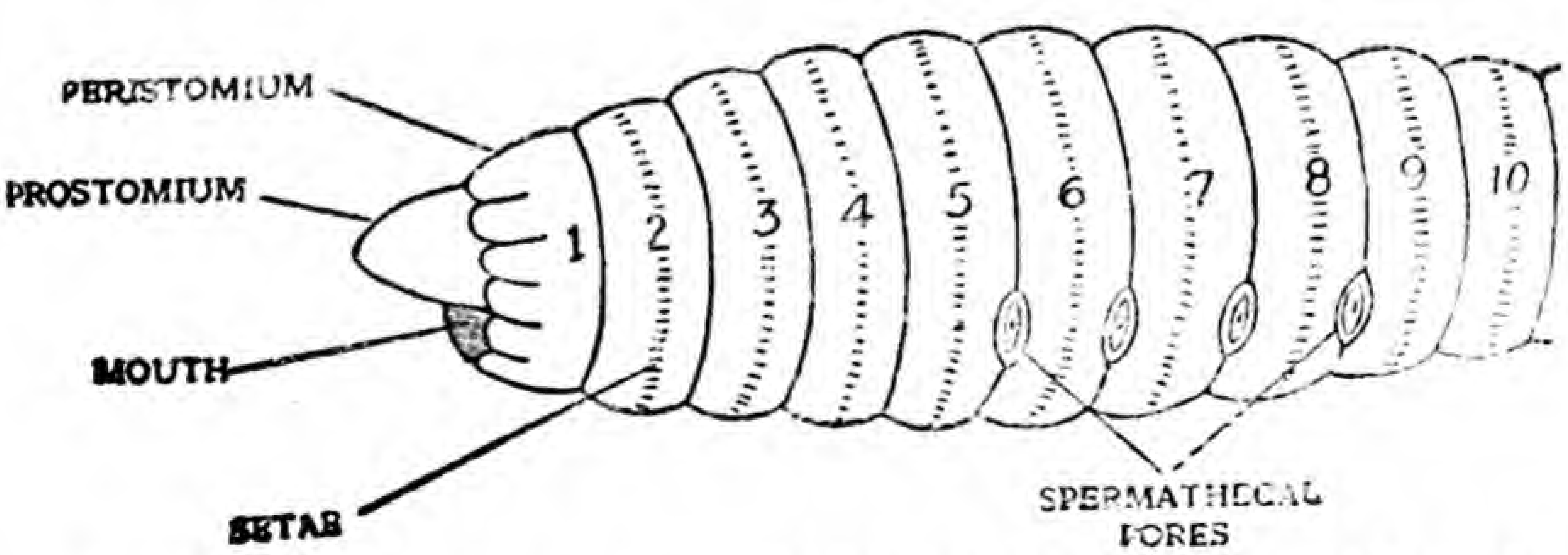


Fig. 11.4. *Pheretima posthuma* (anterior region in lateral view)

(vii) Nephridiopores. These are numerous exceedingly fine pores scattered irregularly over all the segments except the first two.

Body-wall (Figs. 11.5, 11.6 and 11.7).

Structure. The body-wall of earthworm consists of four layers : **cuticle, epidermis, muscles and coelomic epithelium.**

1. **Cuticle**. The cuticle is a thin, noncellular, iridescent layer which covers the body externally. It is composed of the fine layers of collagen

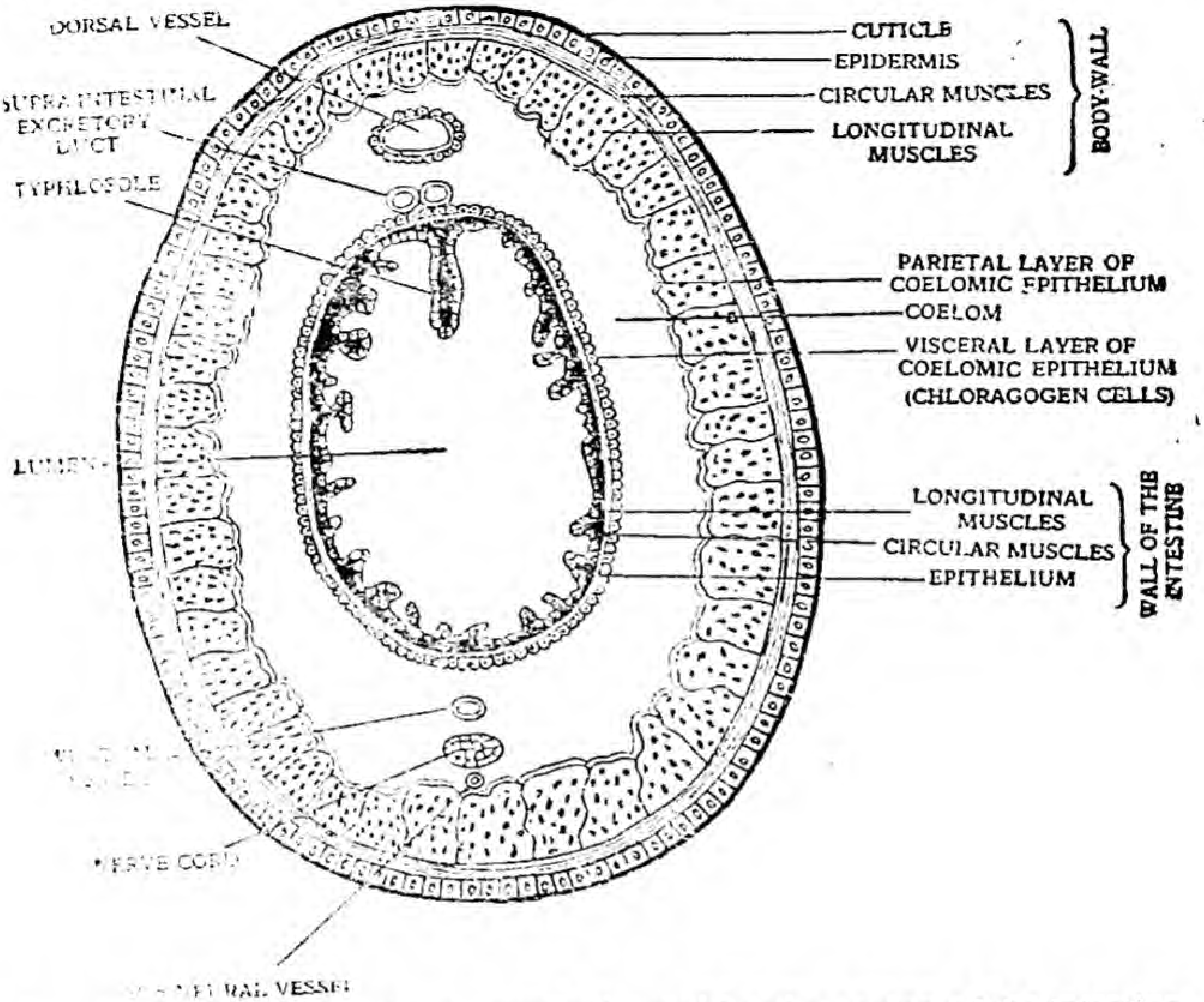


Fig. 11.5. T.S. *Pheretima* through the typhlosolar region of the intestine

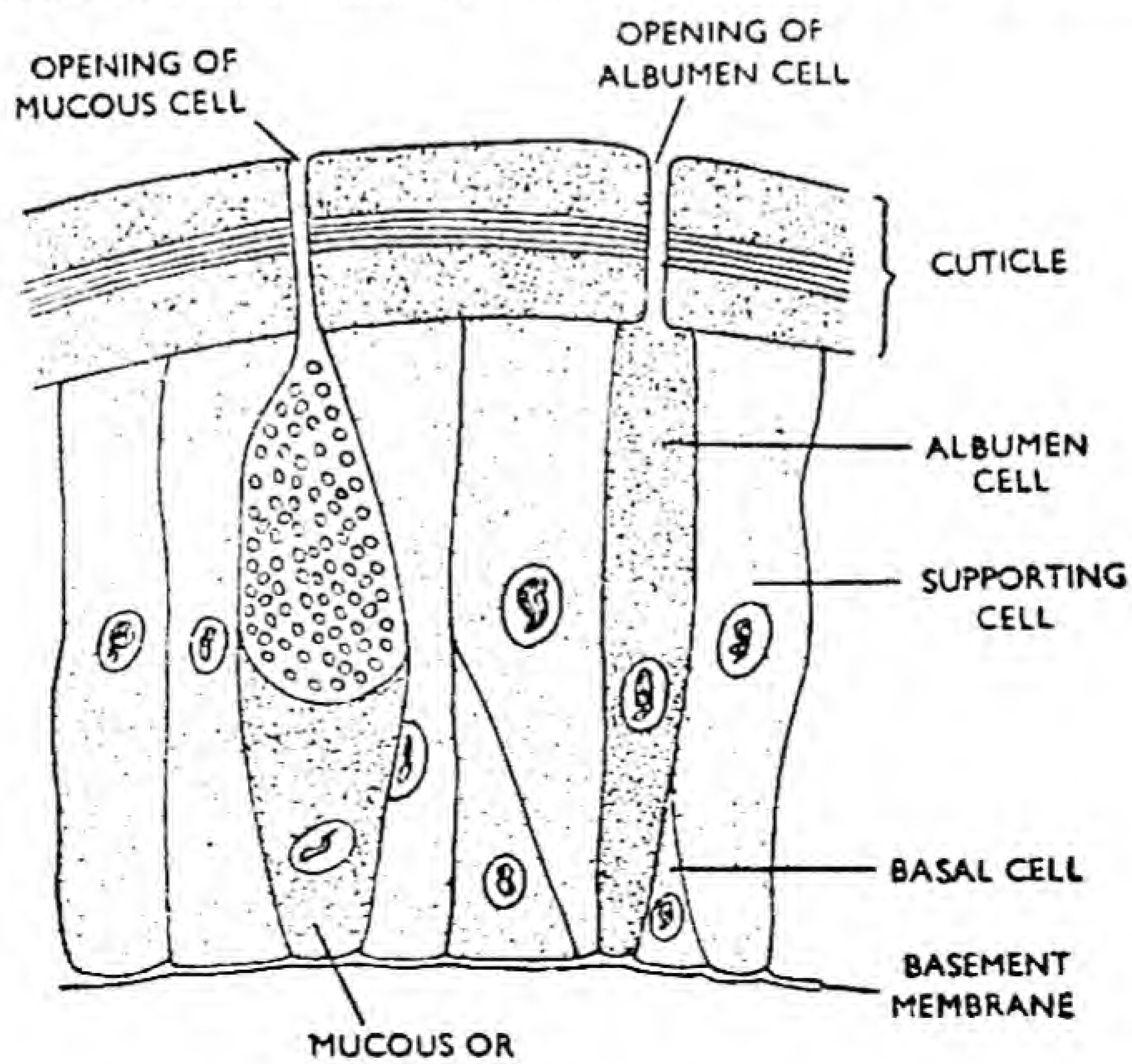


Fig. 11.6. Epidermis and cuticle of earthworm

fibres, the fibres of each layer being at right angles to those of the layer next above or below it. It is perforated by numerous minute pores through which the nephridia and epidermal glands open out. The cuticle is secreted by the columnar or supporting cells of the underlying epidermis.

2. **Epidermis.** The epidermis (Fig. 11.6) consists of a single layer of **columnar** or **supporting cells** resting on a **basement membrane.** Interspersed among the columnar cells are the **gland cells, sensory cells** and **basal cells.** The gland cells are of two types : the **mucous cells** and the **albumen cells.** They discharge their secretions, **mucus** and **albumen,** through pores in the overlying cuticle. The sensory cells occur in small groups and have protoplasmic processes at their outer end. The basal cells are small undifferentiated cells filling up the spaces between the inner ends of the other epidermal cells. They later give rise to the glandular and supporting cells of the epidermis and may, therefore, be called "replacing cells" also.

3. **Muscles.** The muscles are arranged in two layers : an outer thin layer of **circular muscles** and an inner thick layer of **longitudinal muscles.** Contraction of the circular muscles makes the body long and thin while that of the longitudinal muscles makes it thick and short. The longitudinal muscles are arranged in bundles, each bundle separated

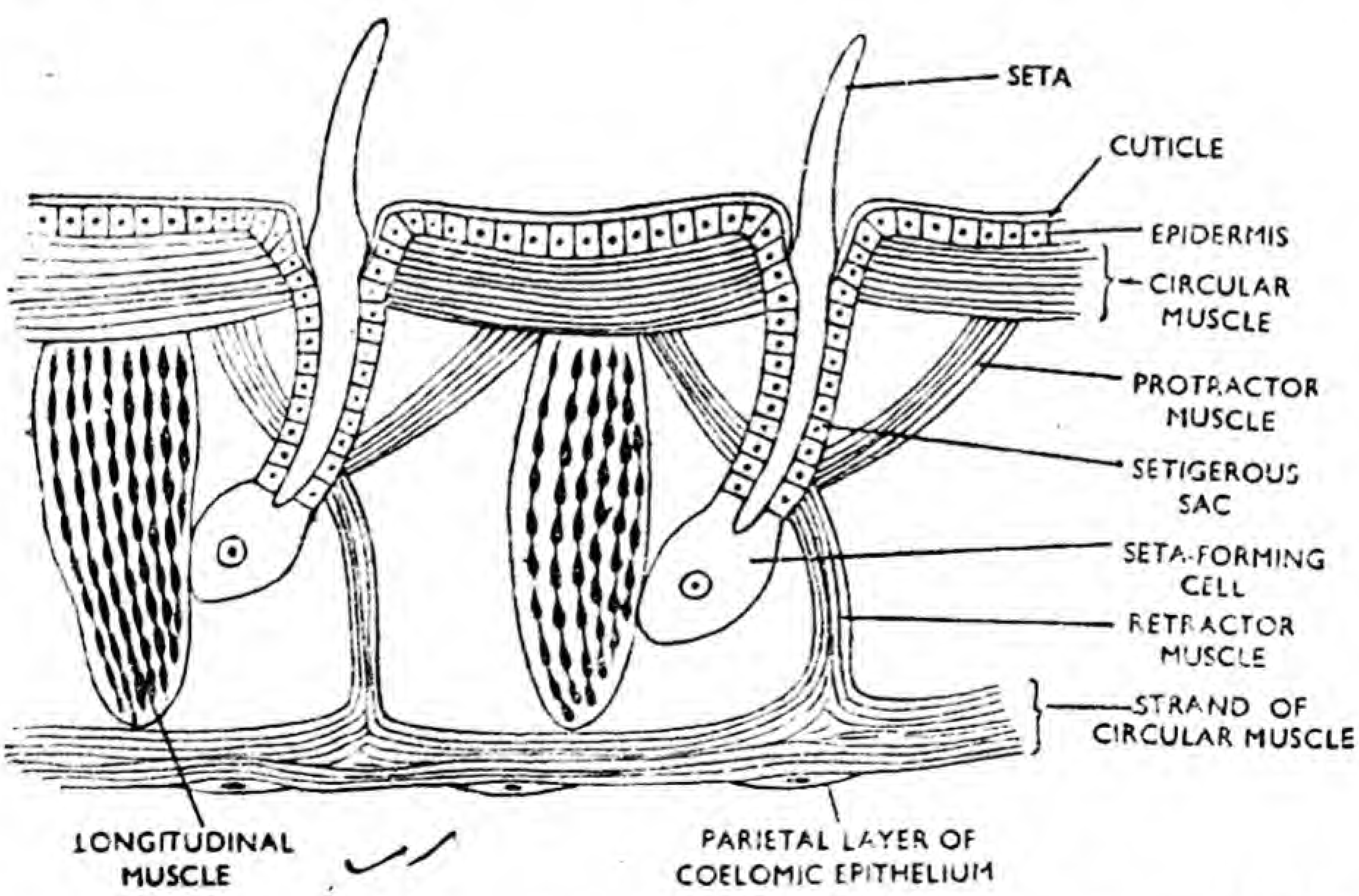


Fig. 11.7. T.S. of a part of the body-wall of earthworm through the setal ring ; showing insertion and muscles of the setae

from its neighbour by connective tissue septa. A long narrow strip of muscle fibres runs along the inner surface of the skin in the mid-dorsal line. The dark mid-dorsal streak visible on the skin externally is due to the presence of this strip. The body-wall musculature consists of smooth muscle fibres.

4. **Coelomic Epithelium.** The coelomic epithelium covers the body-wall internally. It is composed of thin squamous cells. As it forms the outer boundary of coelom, it is called the **parietal layer of coelomic epithelium or parietal peritoneum.**

The **setae** are embedded in the ingrowths of epidermis called the **setigerous sacs.** Each seta is secreted by a single large epidermal cell lying at the bottom of the setigerous sac. To the base of each setigerous sac are attached two sets of muscles : the **protractor** which radiates outward and joins the circular muscles and the **retractor** which runs inwards to join a special band of circular muscles situated outside the parietal peritoneum in this region. These muscles serve to protrude and withdraw the setae respectively. The setae are composed of chitin hardened and strengthened by impregnation of **scleroprotein.** When worn out, the setae fall out and are replaced by new ones.

Functions. The body-wall protects the internal more delicate structures from mechanical injury. The cuticle checks excessive evaporation. The epidermis is the main seat of respiration. The mucus secreted by the mucous glands moistens the skin to aid in respiration, lubricates the body to help in locomotion and cements the walls of the burrow of the worm. The albumen serves as the food for the worm developing inside the ootheca (see ootheca formation, page 169). The sensory cells receive external stimuli. The muscles are responsible for movements. The setae help in locomotion. The peritoneum secretes coelomic fluid.

Coelom, Coelomic Fluid and Lymph Glands

Coelom. The coelom is the space between the body-wall and the viscera (Fig. 11.5). It is lined externally by parietal peritoneum and internally by visceral peritoneum. It is divided into a series of compartments by vertical partitions or **septa** which stretch across the coelom from the intersegmental grooves of the body-wall to the alimentary canal (Fig. 11.10). The first septum lies between the fourth and the fifth segments so that the coelom in the first four segments is undivided. It is, however, traversed by a number of muscular strands which connect the body-wall with the buccal cavity and the pharynx. The first septum is very thin whereas the next five septa are thick and muscular. One septum, either between the eighth and ninth or ninth and tenth segments is almost always absent. All the six anterior septa are oblique and cone-shaped, the apices of the cones being directed backwards. The remaining septa are all thin and vertical. The first nine septa are complete partitions having no apertures in them. Each of the succeeding septa is perforated by a number of oval or rounded apertures having sphincter muscles round them. The septa consist of a double layer of peritoneum enclosing a thin sheet of connective tissue and muscle-fibres.

Coelomic Fluid. The coelom contains a milky fluid, the **coelomic fluid.** This fluid has four types of cells or corpuscles : **amoeboid cells or phagocytes, circular cells, yellow cells** or **chloragogen cells,** and **mucocytes** (Fig. 11.8). The phagocytes are the largest and most numerous. They

show amoeboid movements and can devour foreign bacteria. Their cytoplasm is full of ingested granules or bacteria. The yellow cells are very small but almost as numerous as the phagocytes. They have

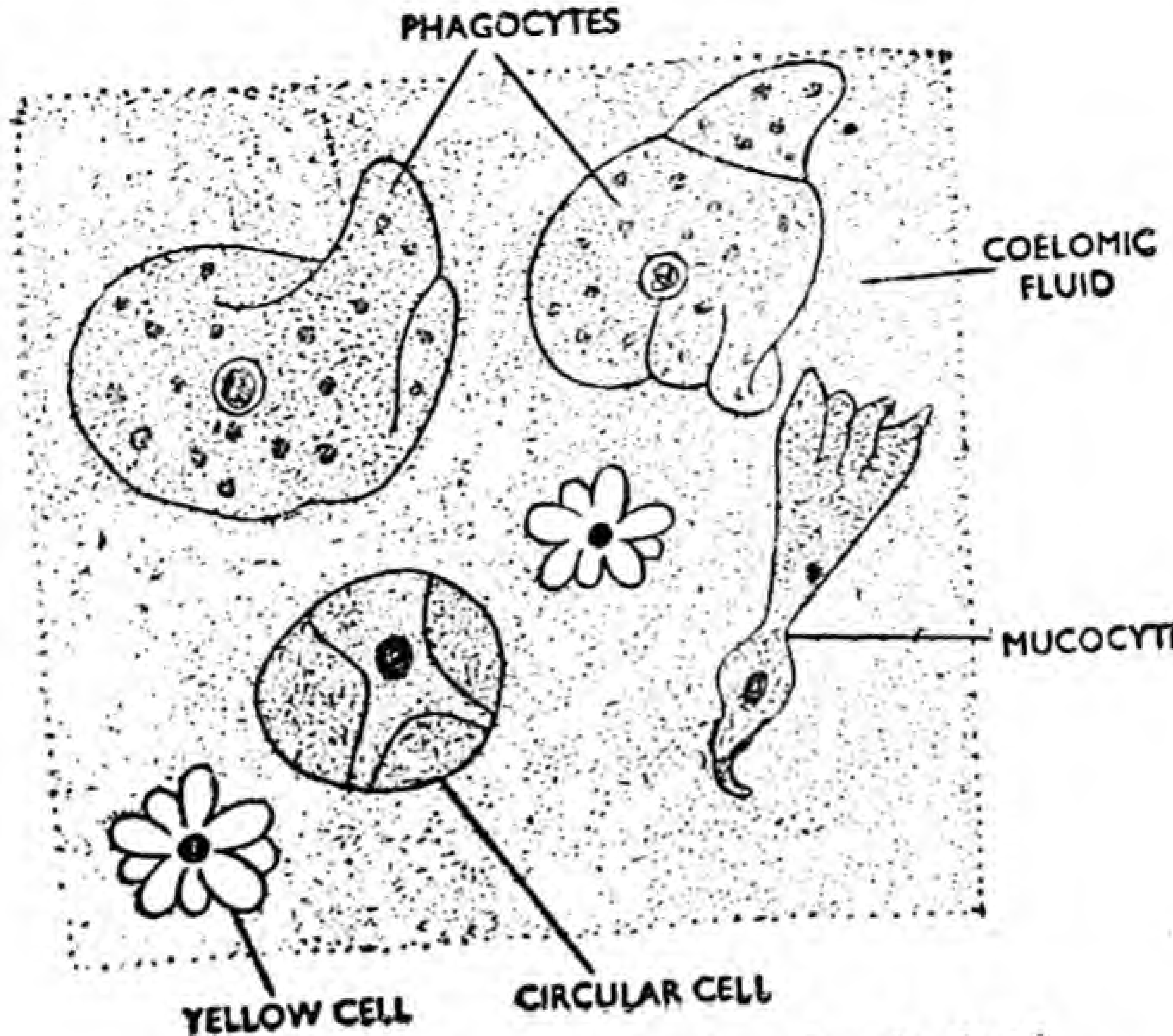


Fig. 11.8. Corpuscles of coelomic fluid

vesicular outgrowths on their periphery, giving them star-like appea-rance. The circular cells are very few and are intermediate in size between the phagocytes and the yellow cells. The mucocytes have one end expanded like a fan. The coelomic fluid oozes out through the dorsal pores and serves many functions. It keeps the skin moist for respiration. It disinfects the skin by killing bacteria which are engulfed by the phagocytes. It aids in excretion by eliminating yellow cells which are full of waste material. The coelomic fluid also helps in fixing the setae into the ground during locomotion. This is brought about by making certain segments of the body turgid and stiff by restricting coelomic fluid to them by closing sphinctered apertures of the septa between them.

Lymph Glands. The lymph glands are small paired organs present in the coelom on the sides of the dorsal vessel from the segment 26 on-wards. They also contain the phagocytes. The latter ingest foreign bodies and digest them.

Locomotion (Fig. 11.9.)

The earthworm moves by contractions of the body-wall muscles aided by setae. Locomotion starts with a contraction of the circular muscles in a limited region of the anterior part of the body. The con-traction makes the region thin and thus exerts pressure on the coelomic fluid contained therein. This pressure causes elongation of that region by relaxation of longitudinal muscles. The contraction of circular muscles passes backwards over the body like a peristaltic wave so that thinning and elongation gradually affect more and more posterior

segments. When the contraction has covered some distance, the setae of the anterior segments are protruded and fixed in the soil. The longitudinal muscles of the anterior region now contract, making the region short and thick. As the anterior region is firmly anchored, its shortening pulls the hinder region forwards. The above mentioned waves of

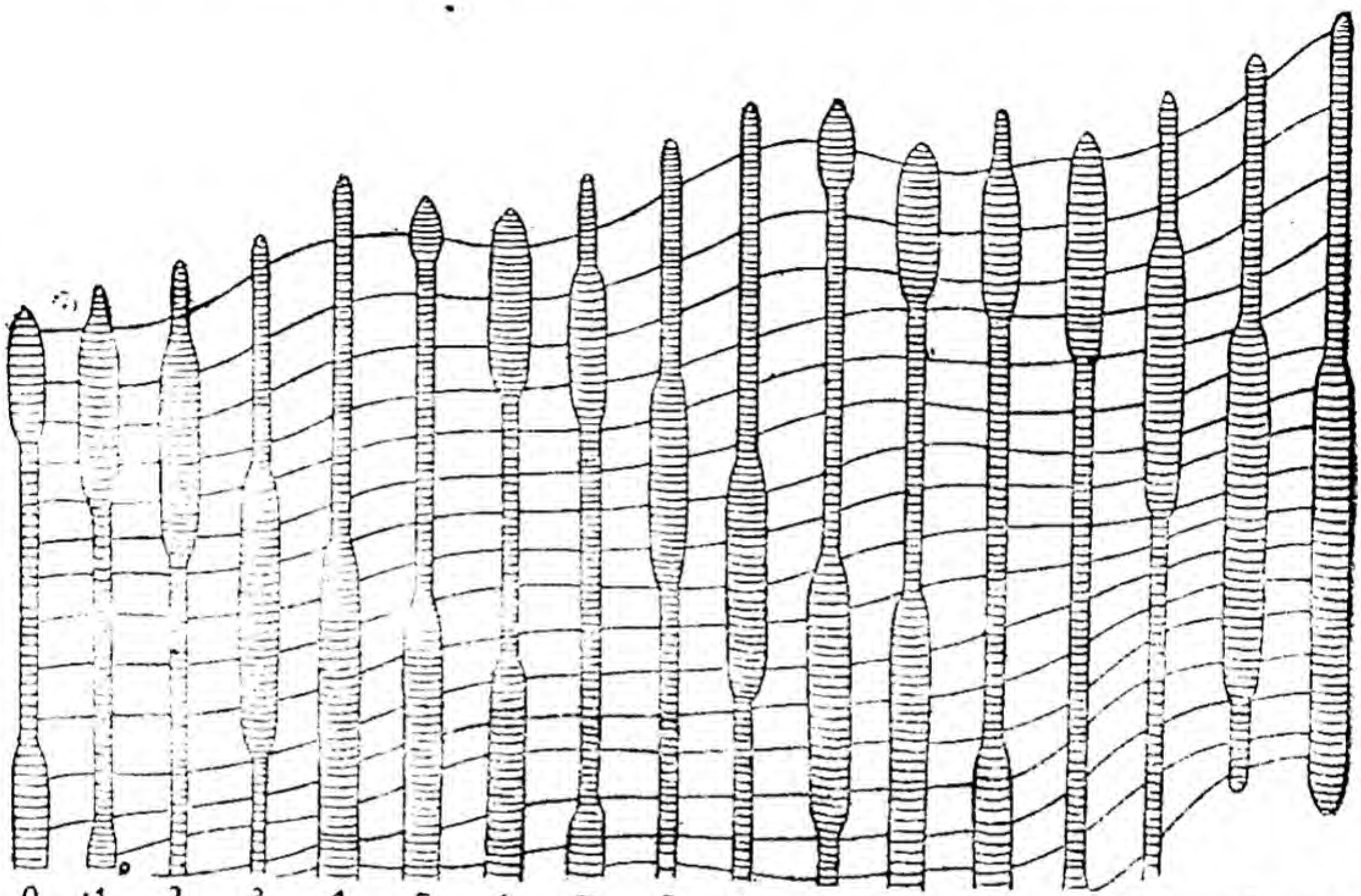


Fig. 11.9. Locomotion in eartworm

contraction of circular and longitudinal muscles extend backwards and are followed by more similar waves passing in a similar alternating manner. At those regions where longitudinal muscles are contracting, the body becomes thick and setae are protruded to grip the substratum. Where circular muscles are contracting, the body becomes thinner and the setae are withdrawn to make the part free so that it slips ahead. It, thus, follows that only a part of the worm's body is moving at a time. This can be easily seen in a living worm.

The septa also help in locomotion. They act as water-tight partitions to prevent flowing away of the coelomic fluid from the region of pressure so that the fluid may cause elongation of the region under pressure.

Earthworm finds it difficult to move on a hard surface as the setae cannot anchor the body.

The earthworm can move backwards also. The backward movement is a normal affair during withdrawal into the burrow.

Locomotion is controlled by the nerve-cord. This is indicated by the fact that a worm devoid of cerebral and subpharyngeal ganglia moves about almost normally.

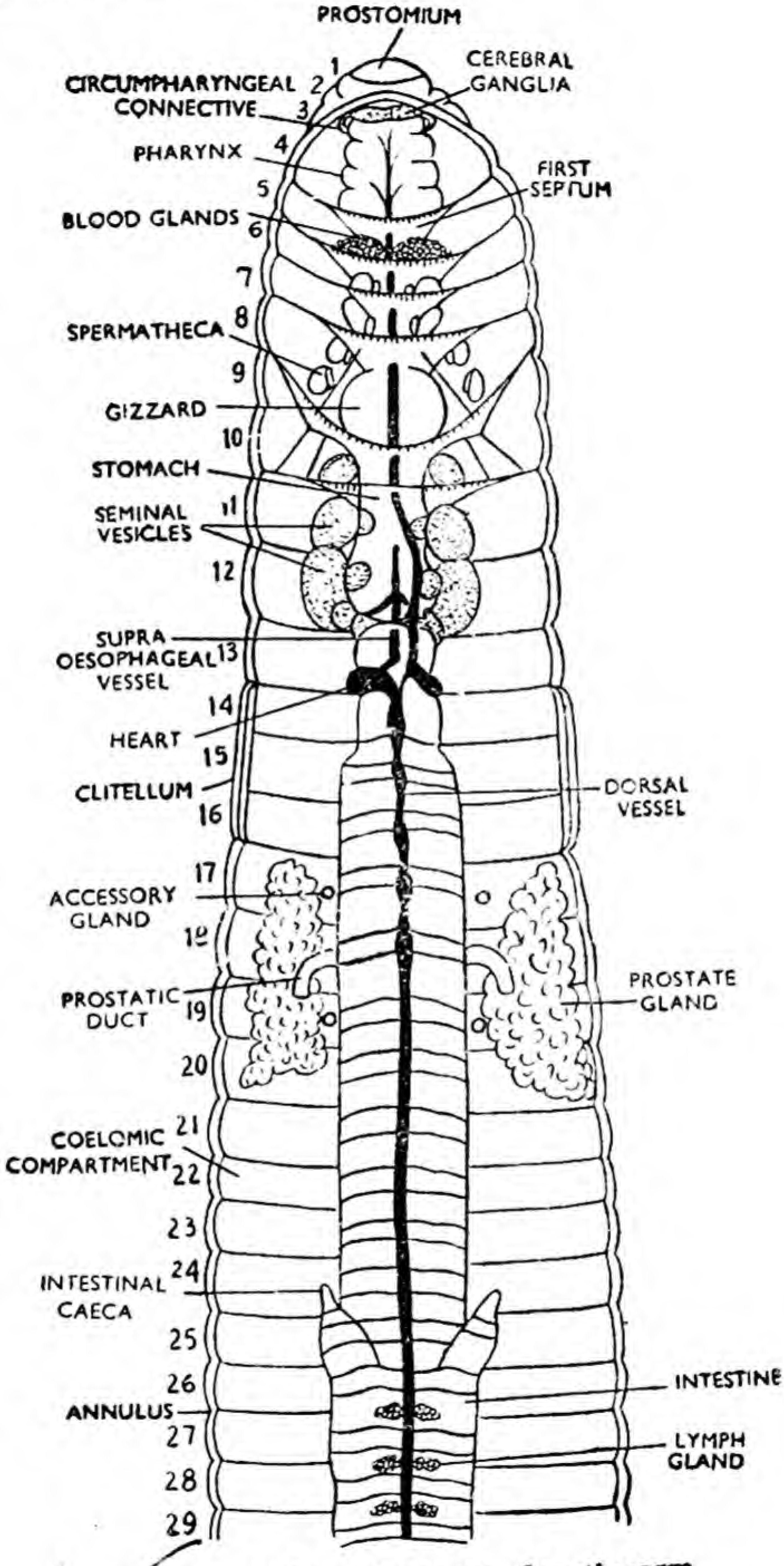


Fig. 11.10. Anatomy of earthworm

Digestive System (Fig. 11.12)

The digestive system digests the food, *i.e.* it changes the food

chemically and mechanically into a form which can diffuse into the blood.

Morphology. In the earthworm the digestive system is complete, *i.e.* it has an aperture for egestion in addition to one for ingestion. It consists of a long **alimentary canal** and some **digestive glands** associated with it.

1. Alimentary Canal. The alimentary canal is a straight tube of varying diameter. It extends along the entire body. It is held in position by the successive transverse intersegmental septa which extend between it and the skin. The alimentary canal comprises many parts : **mouth, buccal cavity, pharynx, oesophagus, intestine** and **anus.**

(*a*) **Mouth.** The mouth is a crescentic aperture situated on the anterior face of first segment or **peristomium.** It is overhung by a small fleshy lobe, the **prostomium.** It leads into the buccal cavity.

(*b*) **Buccal Cavity.** The buccal cavity is a small thin-walled chamber extending from the first to the middle of the third segment. It is held in position by muscle-strands which pass forwards and backwards from its surface to the body-wall. The buccal cavity is followed by the pharynx.

(*c*) **Pharynx.** The pharynx is a pear-shaped sac. It extends up to the end of the fourth segment. It is marked off from the buccal cavity externally by a dorsal groove which lodges the brain. Roof of the pharynx is depressed by the presence on it of **pharyngeal mass or bulb** (to be described later). Consequently, the cavity of the pharynx is broad laterally but low dorso-ventrally. (Fig. 11.11). The lateral walls of the pharynx deeply project into its cavity in the form of two horizontal shelves. Several radial muscle-strands pass from the surface of the pharynx to the body-wall. These muscle-strands by their contraction dilate the pharyngeal cavity during swallowing. They are called the **dilator muscles.** The pharynx opens behind into the oesophagus.

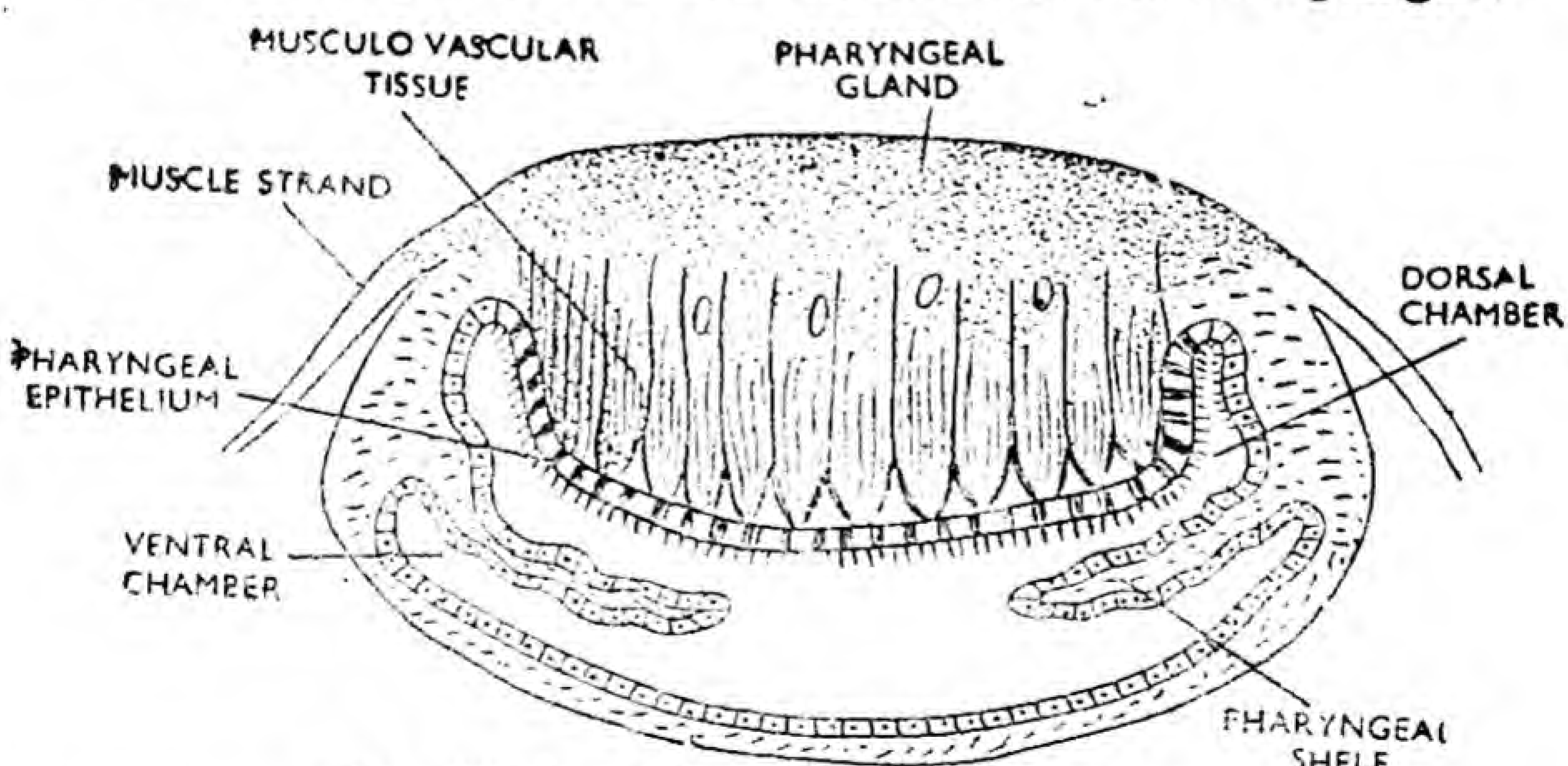


Fig. 11.11. T.S. pharynx of earthworm

(*d*) **Oesophagus.** The oesophagus is a long and narrow tube. It extends up to the end of the fourteenth segment. In the eighth segment or in eighth and ninth segments, when their intervening septum is missing, the oesophagus is modified to form an oval sac, the **gizzard.** The gizzard is a hard muscular organ with a thick wall lined internally by cuticle. It serves to reduce the food to a fine state by contractions of

its muscular wall. Behind the gizzard the lining of the oesophagus is transversely folded, highly vascular and glandular. This region has a sphincter at each end and is sometimes regarded as the **stomach**. It is followed by the intestine.

(*e*) **Intestine.** The intestine is a wide, thin-walled tube extending from the fifteenth segment to the end of the body. It shows three distinct regions :

(*i*) The **pre-typhlosolar region** which extends from the fifteenth to the twenty-sixth segment. It is characterised by the possession of a highly vascular and folded lining. In the twenty-sixth segment, a pair of conical outgrowths, the **intestinal caeca**, arise from this region and extend forwards over three or four segments.

(*ii*) The **typhlosolar region** which starts from the twenty-seventh segment and terminates twenty-three or twenty-five segments ahead of the hind end of the body. It is distinguished by the presence of a large mid-dorsal projection, the **typhlosole**, hanging into the lumen of the intestine in addition to low folds over the entire inner surface.

(*iii*) The **post-typhlosolar region** or **the rectum** which occupies the last twenty-three or twenty-five segments. It is without a typhlosole and contains the faecal matter.

(*f*) **Anus.** The anus is a slit like aperture on the posterior face of the last or anal segment.

The wall of the alimentary canal consists of three layers : the **coelomic epithelium, muscles** and **enteric epithelium** (Fig. 11.5).

The **coelomic epithelium** covers the alimentary canal externally and consists of tall narrow cells. As it covers the viscera and forms the inner boundary of the coelom, it is often called the **visceral layer of coelomic epithelium** or **visceral peritoneum**. The cells of this layer over the oesophagus, intestine and rectum are full of minute yellow granules and are called the **"yellow** or **chloragogen cells"**. These cells are excretory in function. They collect waste materials from the blood-capillaries and, when full, fall into the coelomic fluid from where they are eliminated

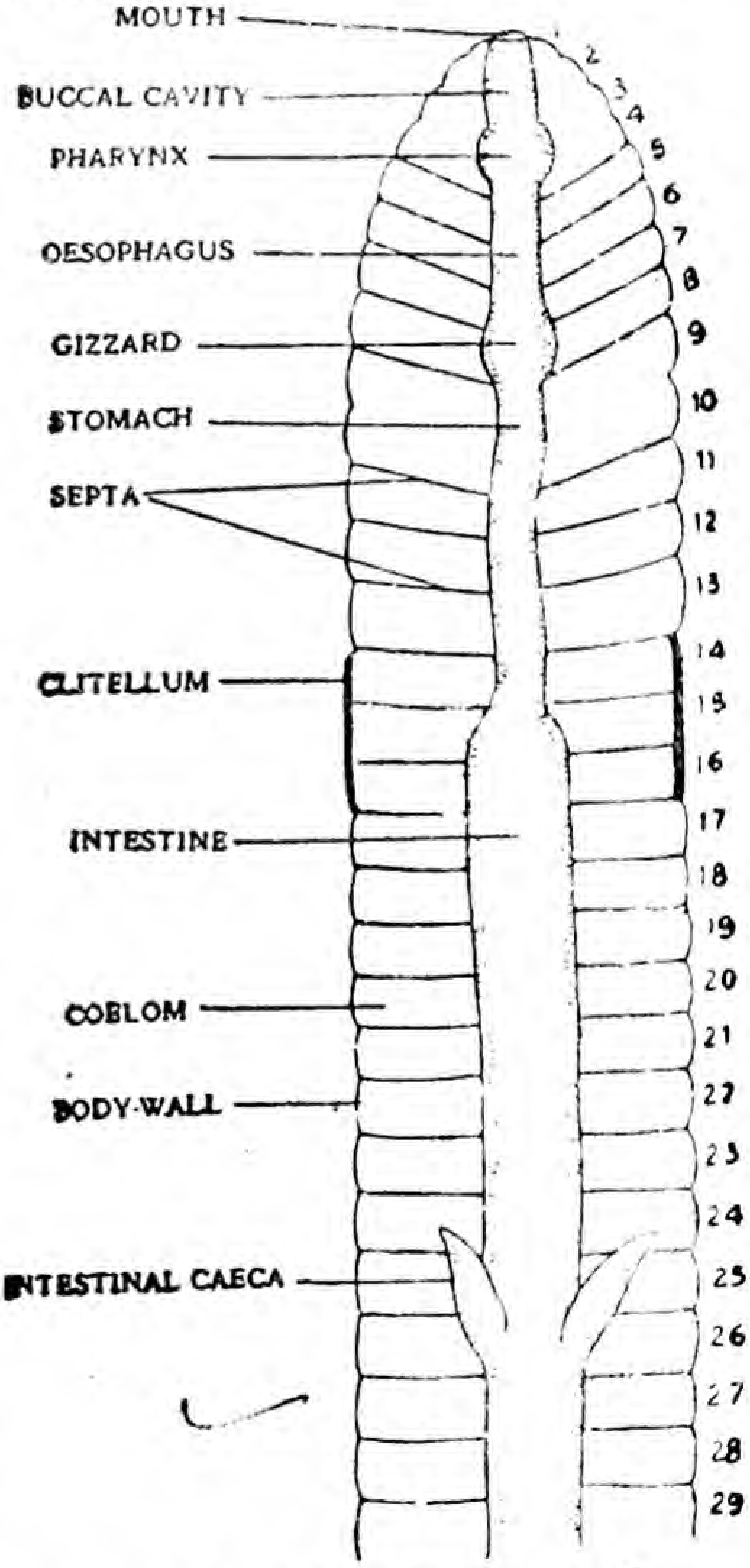


Fig. 11.12. Digestive system of *Pheretima posthuma*

through the dorsal pores and nephridia. The chloragogen cells are also considered to store reserve food in them.

The **muscles** are differentiated into the outer longitudinal and the inner circular muscles. The two muscular coats vary in development in different regions of the alimentary canal. Both the coats are feebly developed in the intestine but well-developed in the oesophagus, pharynx and buccal cavity. The gizzard has circular muscles only. All the muscles of the alimentary canal are unstriped.

The **enteric epithelium** lines the cavity or lumen of the alimentary canal and consists of tall nutritive cells and vacuolated gland cells.

2. Digestive Glands. There are three types of digestive glands associated with the alimentary canal of the earthworm. A prominent gland called the **pharyngeal mass** or **bulb** is situated on the roof of the pharynx. It secretes a proteolytic or protein-digesting enzyme and mucus, which are discharged into the pharynx by fine ducts. The epithelial lining of the oesophagus behind the gizzard contains gland cells which also secrete a proteolytic enzyme. The gland cells are also present in the epithelium of the intestine. These cells secrete all the three types of enzymes, namely, proteolytic, amylolytic or starch-digesting and lipolytic or fat-digesting.

Food. The food of earthworm consists mainly of dead organic matter present in the soil. To get this food, the worm swallows enormous quantities of soil. It also feeds directly on bits of leaves and green algae growing on the moist earth.

Ingestion. For taking food, the worm applies the mouth to the food and expands the pharynx by the contraction of the muscle-bands connecting the pharynx with the body-wall. The enlargement of the pharyngeal cavity draws the food into the buccal cavity by sucking action.

Digestion. Digestion in earthworm is intercellular or extra-cellular. In the pharynx, the food meets the secretion of the pharyngeal mass. This secretion lubricates the food with its mucus and begins to digest the proteins with its proteolytic enzyme. In the gizzard, the food is ground up by the contractions of its muscular walls. The soil particles swallowed with the food probably help in the grinding operation. Behind the gizzard the food receives another proteolytic enzyme, which digests more proteins. The digestion is completed in the intestine where proteins are broken into amino acids by the proteolytic enzyme, the starches are converted into sugars by the amylolytic enzyme and the fats are changed into fatty acids and glycerine by fat-splitting enzyme.

Food is slowly pushed backwards by rhythmic waves of contraction passing along the alimentary canal from the anterior to the posterior end. This is called **peristalsis.**

Absorption. The digested food diffuses through the wall of the intestine and enters the blood. This is known as absorption. The blood distributes the food to all the parts of the body.

Assimilation. The food is ultimately converted into the protoplasm of the worm in the cells. This is called **assimilation.**

Egestion. After the useful matter has been digested and absorbed in the intestine, the residue collects in the rectum and changes into faeces. The faeces is finally voided out on the surface of the soil through the anus as the familiar "**worm castings**".

Growth

Growth in earthworm occurs uniformly in all parts of the body. It involves the division of all the cells except the nerve-cells.

Respiratory System

The respiratory system provides oxygen to the body and removes carbon dioxide from it.

Earthworm does not possess special organs for respiration. It takes place through the skin and is called **cutaneous respiration**. The skin is remarkably adapted for this function. It is thin, moist and highly vascular. It is kept moist by the moisture of the soil, the mucus secreted by the gland cells of the epidermis and the coelomic fluid oozing out of the dorsal pores. Oxygen from the air dissolves in these fluids. This oxygen has greater partial pressure than that in the blood of the capillaries. Therefore, this oxygen diffuses into the blood through the thin skin. The blood contains a respiratory pigment called **haemoglobin** which greatly increases its capacity for oxygen absorbing. Haemoglobin loosely combines with oxygen to form oxyhaemoglobin. From the skin the blood with its oxyhaemoglobin goes to the internal organs. Here oxyhaemoglobin breaks up into oxygen and haemoglobin. The oxygen diffuses from the blood into the cells of the internal organs because the cells have lower oxygen concentration. In the cells, oxygen is utilized in the oxidation of food to liberate energy for the life activities. The oxidation produces carbon dioxide, which, because of having a greater partial pressure in the cells than in the blood, diffuses out of the cells into the plasma of the blood. The blood with carbon dioxide returns to the skin. This carbon dioxide in the skin capillaries has greater partial pressure than that outside the worm. Therefore, it leaves the blood by diffusion through the skin.

From the above account we find that respiration, *i.e.* the exchange of gases, is of two types. In the skin the blood absorbs oxygen and gives up carbon dioxide. This is called **external respiration.** In the internal organs or tissues, the blood distributes oxygen and collects carbon dioxide. This is known as the **internal** or **tissue respiration.**

Nervous System (Figs. 11.13 and 11.14).

The nervous system controls and co-ordinates the working of all parts of the body.

The nervous system in the earthworm is more highly organised than in *Obelia*. It is divisible into three parts : **central nervous system, peripheral nervous system and autonomic nervous system.**

1. Central Nervous System. It comprises a pair of **suprapharyngeal ganglia**, a pair of **peripharyngeal connectives**, a pair of **subpharyngeal ganglia** and the **ventral nerve-cord.** The suprapharyngeal ganglia, also called the **cerebral ganglia**, are situated in the third segment above the alimentary canal in the groove between the buccal cavity and the pharynx. The two ganglia are fused to form a common mass which is often called the "**brain**". The subpharyngeal ganglia are comparatively small and lie in the fourth segment below the pharynx. The peripharyngeal connectives pass backwards and downwards along the lateral sides of the pharynx and connect the suprapharyngeal ganglia with the

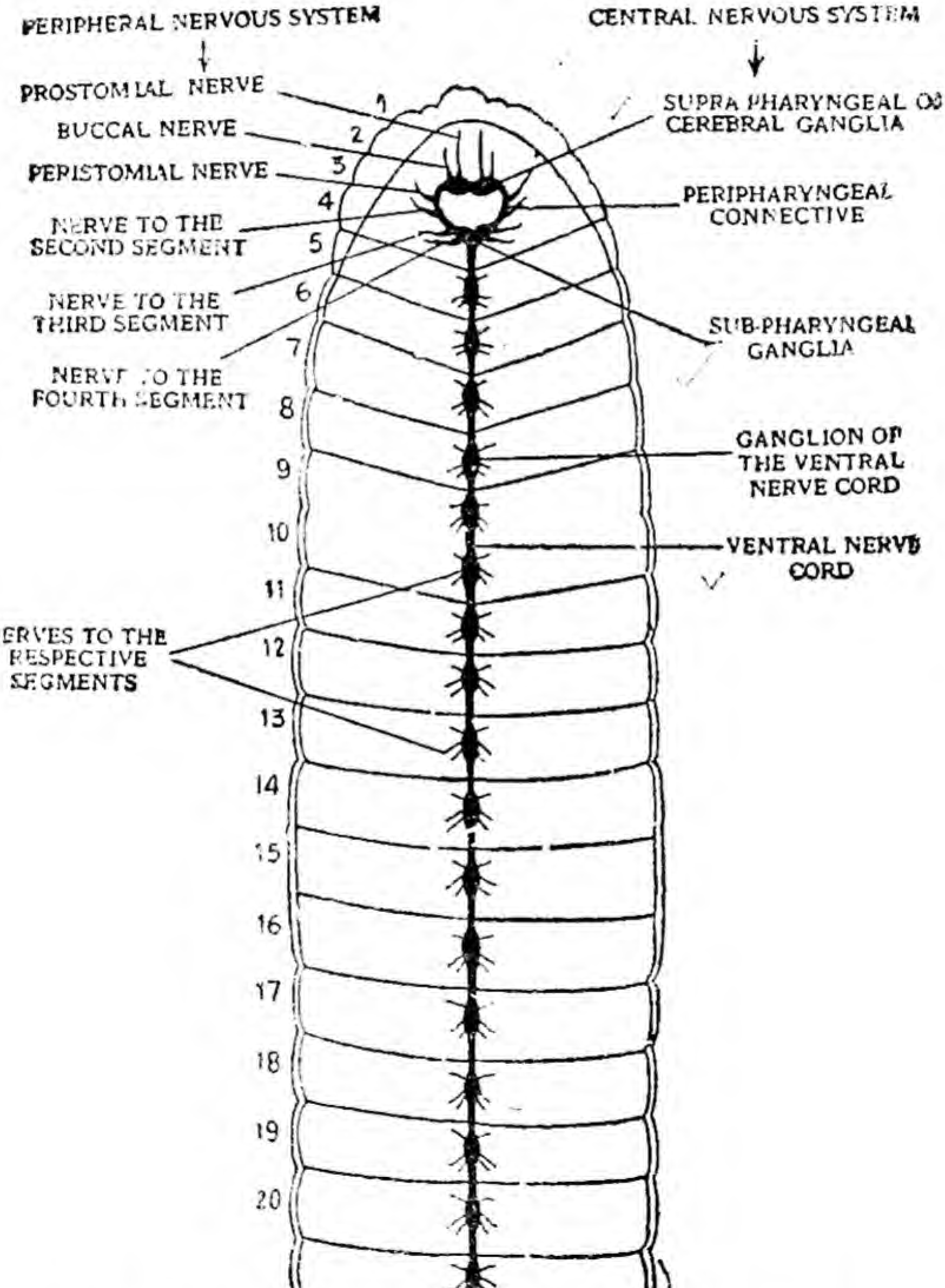


Fig. 11.13. Nervous system of *Pheretima posthuma*

subpharyngeal ganglia. All these structures, thus, form a **nerve-ring** round the pharynx. The ventral nerve-cord extends from the subpharyngeal ganglia to the last segment of the body along **the mid-ventral line**

below the alimentary canal. The apparently single nerve-cord actually consists of two solid cords fused together and enclosed in a common sheath, the **epineurium**, of connective tissue. The epineurium is surrounded by a layer of longitudinal muscle fibres, around which is the peritoneum. In each segment, the nerve-cord bears a swelling, the **segmental ganglion**, which is formed by the fusion of two ganglia.

The entire central nervous system consists of a core of nerve-fibres surrounded by nerve-cells (Fig. 11.14). The nerve-cells are, however, more numerous in the ganglia.

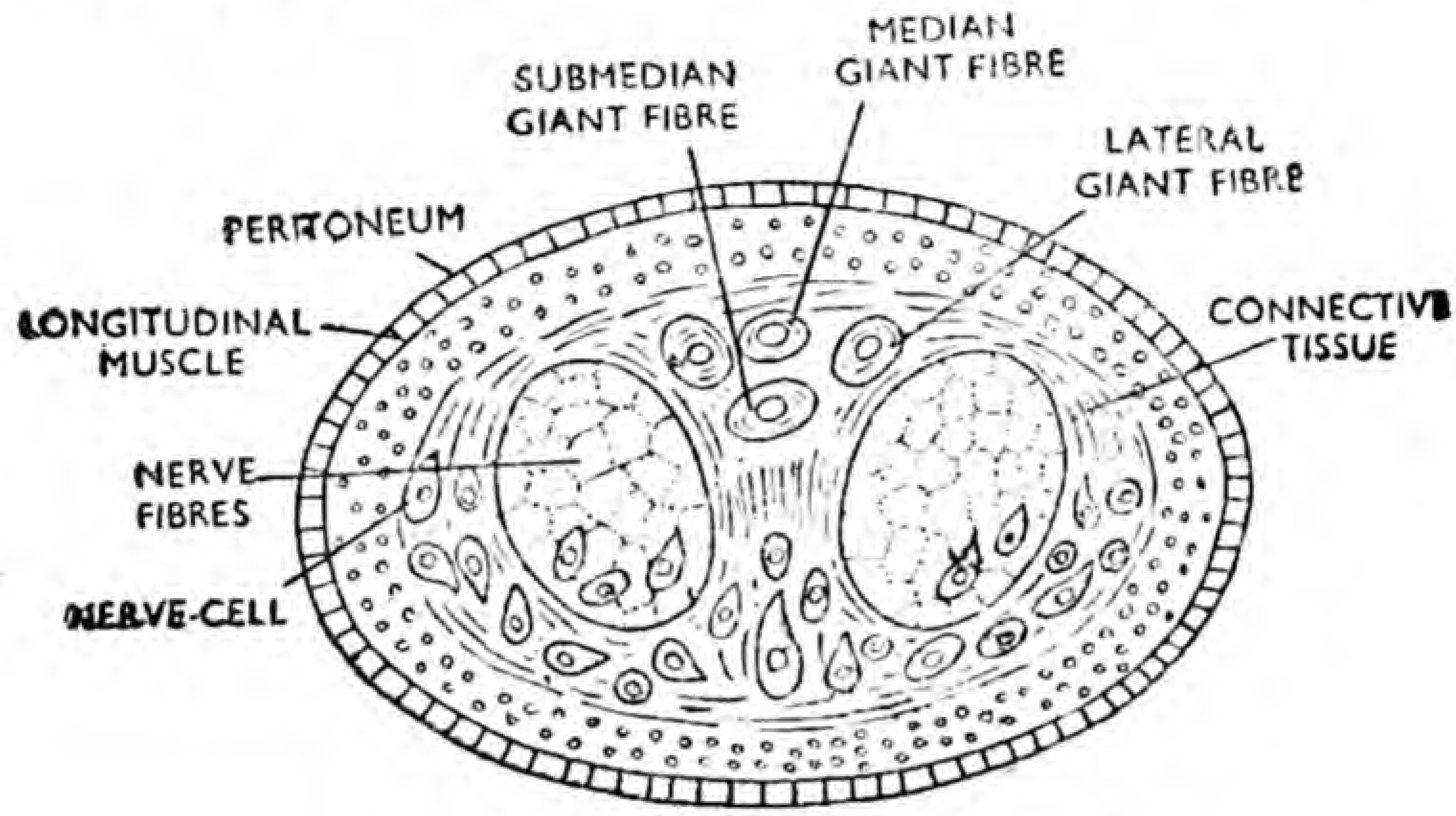


Fig. 11.14. T.S. Nerve-chord

2. **Peripheral Nervous System.** It consists of nerves which arise from the various parts of the central nervous system and proceed to different

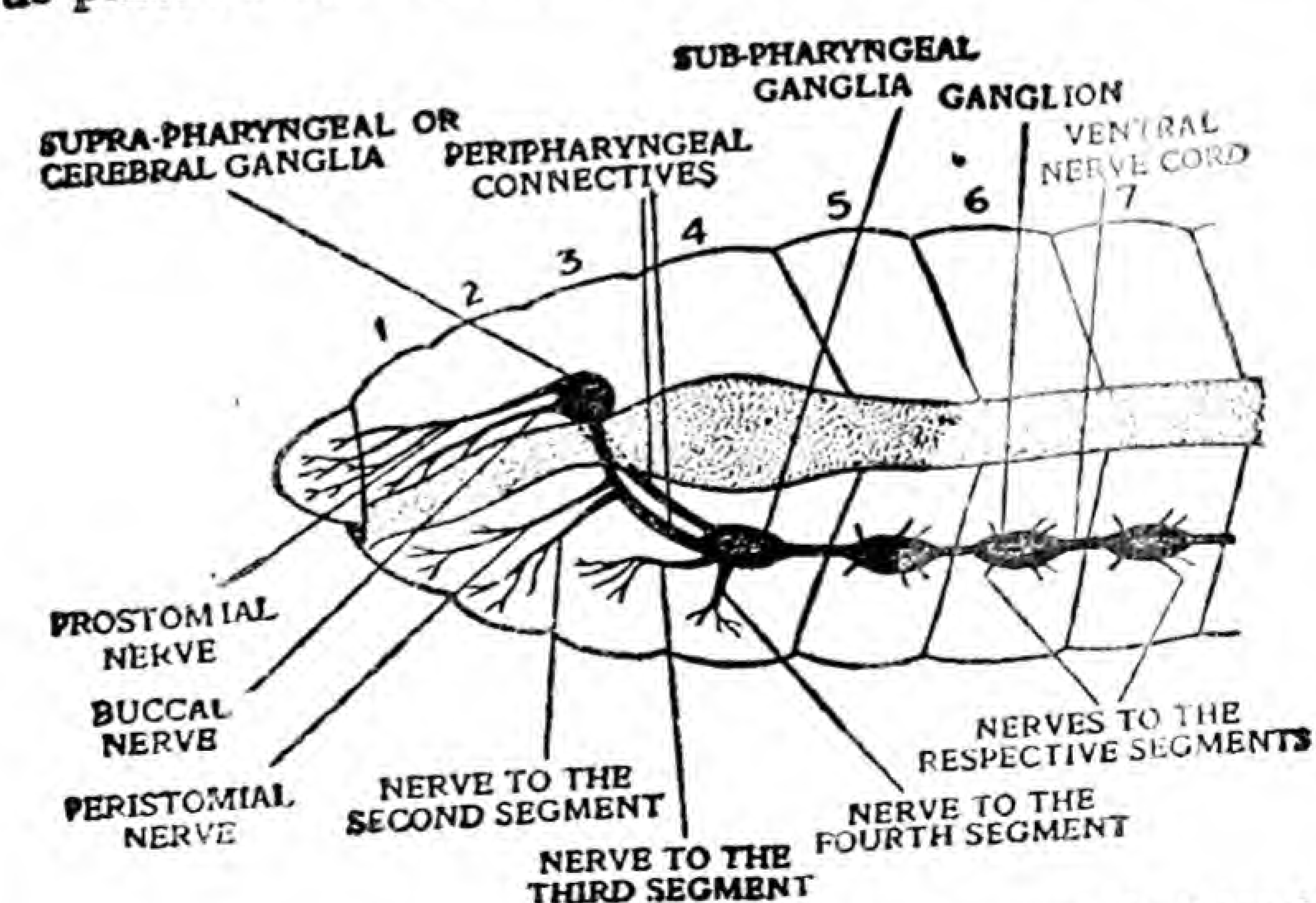


Fig. 11.15. *Pheretima posthuma*—nervous system in lateral view

organs of the body. Two nerves arise from each side of the brain and innervate the prostomium and the buccal cavity by dividing into a

number of branches. Nerves given off from the peripharyngeal connectives supply the first two segments of the body. The subpharyngeal ganglia provide nerves to the third and fourth segments. From each ganglionic swelling of the ventral nerve cord arise three pairs of nerves which are distributed to the organs of their respective segment.

The nerves possess both the **afferent** and the **efferent fibres** so that they are mixed in nature. The afferent fibres connect the nerve-cord with the sensory cells of the epidermis while the efferent fibres connect the muscles with the nerve-cord. The sensory cells of the epidermis receive the external stimuli and convey the sensory impulse to the nerve-cord by the afferent fibres. In the nerve-cord, the sensory impulse is transformed into a motor impulse which is carried to the muscles by the efferent fibres. The muscles then contract in response.

3. **Autonomic nervous system**. It comprises an extensive plexus of nerve-fibres present between the lining epithelium and the circular muscles of the alimentary canal. The plexus is connected by fibres with the circumpharyngeal connectives.

Sense Organs (Figs. 11.16, 11.17 and 11.18)

The sense organs are meant for receiving the external stimuli. In earthworm, the sense organs are very simple, consisting merely of sensory cells situated in the epidermis either singly or in small groups. Those lying in groups form the tactile, olfactory and taste organs while those occurring singly form the light-sensitive organs or photoreceptors. Organs of hearing are altogether absent so that it is unable to perceive

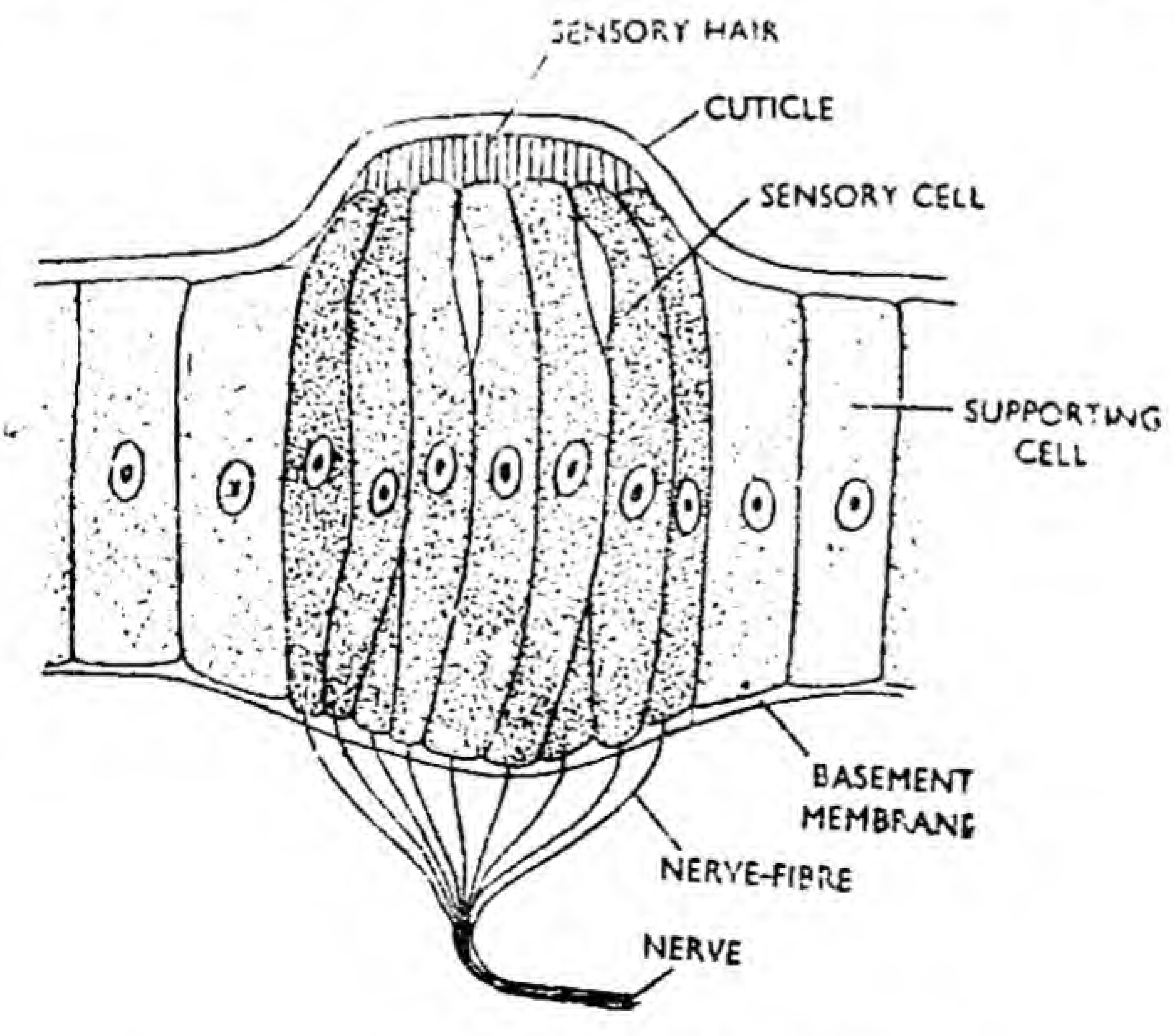


Fig. 11.16. A tactile organ

the sound vibrations. Its skin is, however, highly sensitive to the vibrations in the ground.

(*i*) **Tactile Organs.** These are situated in the epidermis, causing small elevations on the surface of the skin. They are distributed over the entire body but are more numerous towards the anterior side. Each tactile organ consists of a cluster of long, narrow, somewhat spindle-like sensory cells surrounded by supporting epidermal cells. The sensory cells have spaces between them and bear fine hair-like processes at their free ends which are covered by cuticle like ordinary epidermal cells. From the bases of these cells arise nerve-fibres that connect them with the central nervous system. Besides responding to the tactile stimuli, the tactile sense organs perhaps can also perceive the chemical stimuli and changes in temperature.

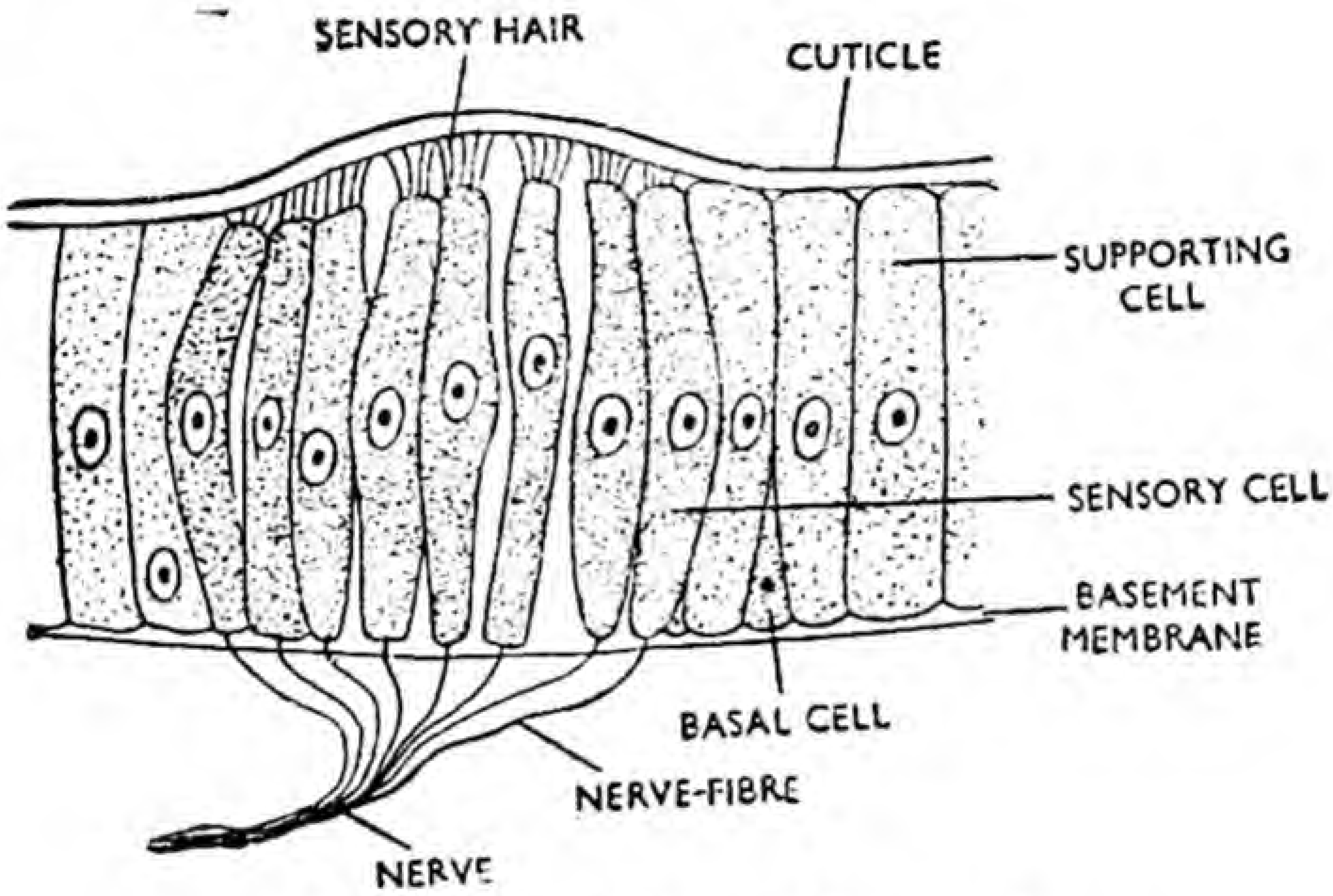


Fig. 11.17. A buccal receptor

(*ii*) **Olfactory** and **Taste Organs.** These are similar to the tactile organs in structure but they lie in the buccal epithelium. They enable the worm to smell and taste the food.

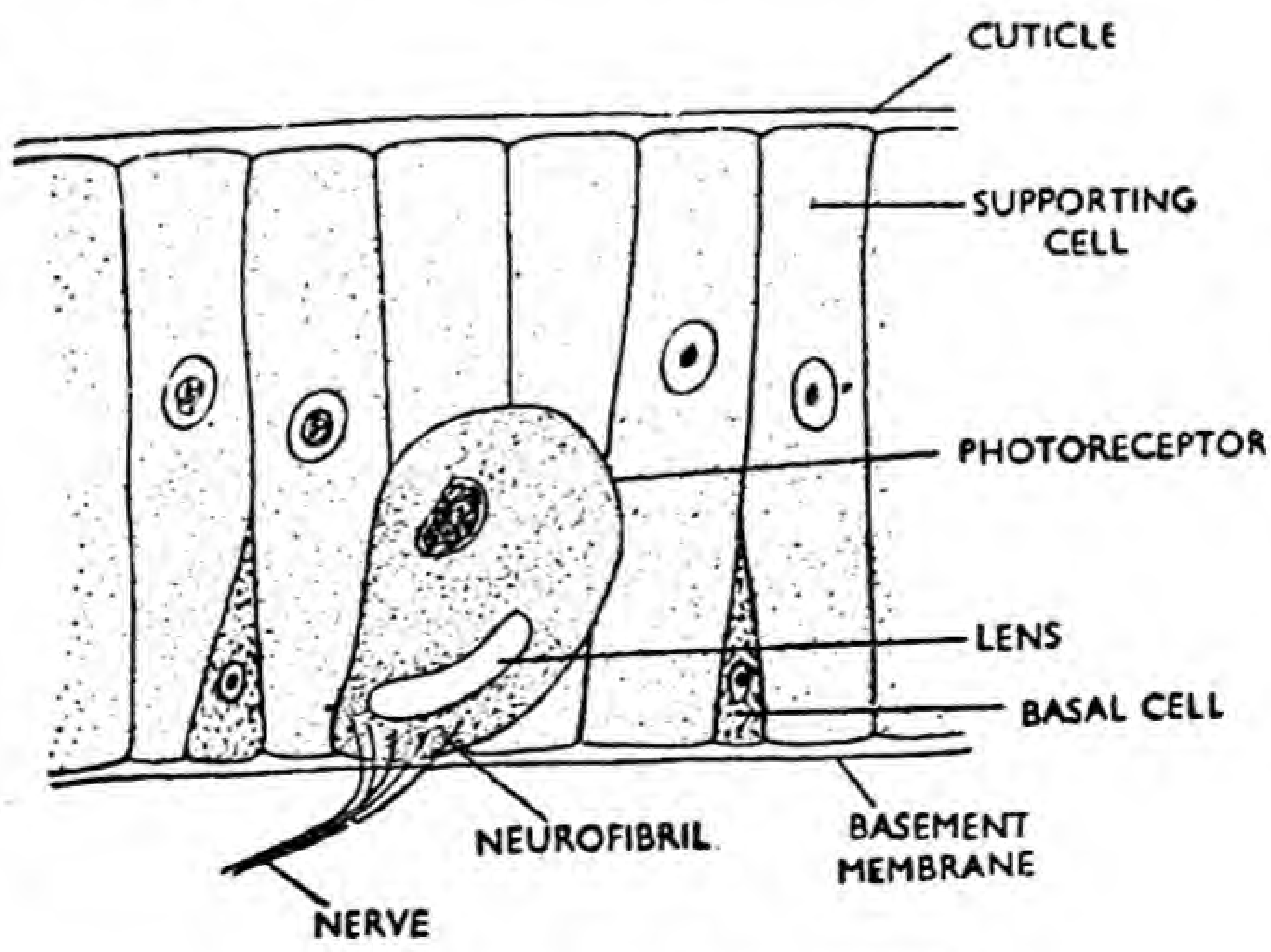


Fig 11.18. A photoreceptor

(*iii*) **Photoreceptors.** These are situated in the deeper part of the epidermis. They are more numerous on the prostomium, but occur on other segments also, though in smaller numbers. A photoreceptor is a short but broad cell with a nucleus and clear cytoplasm. It contains a small, curved, transparent rod, the **optic organelle** or **lens,** which focusses light from almost any angle on fine **neurofibrils** that lie in the lower part of the cell. The neurofibrils may be likened to the retina in the functional sense. They converge into an afferent fibre which leaves the cell at its base and proceeds to the central nervous system. The photoreceptors enable the worm to detect changes in the intensity of light. Being nocturnal in habit, the earthworm avoids strong light.

To detect changes taking place within the body, the worm has minute receptors, called the **proprioreceptors,** in the muscles.

Behaviour

Earthworms are sensitive to all sorts of stimuli. They avoid strong light but can tolerate the dim light of early morning. They respond to very low and very high temperatures by burrowing deeper in the soil. They contract their body when touched. They avoid strong chemical vapours but move towards the food. They like moisture and avoid dryness but leave their burrows if they get flooded with water. We, thus, find that the earthworms react negatively to light, temperature extremes, strong mechanical stimulus and strong chemicals but positively to humidity.

Circulatory System (Fig. 11.19)

The circulatory system serves to transport materials from one place to another in the body.

This system comprises four parts : **blood, blood-glands, blood-vessels** and **hearts.**

1. Blood. The blood is composed of a fluid called **plasm** and cells termed **corpuscles.** The corpuscles are amoeboid, colourless and nucleated. They resemble the leucocytes of vertebrates. The blood is red in colour because it contains a respiratory pigment, the **haemoglobin,** dissolved in the plasma. The blood forms the medium of transport, *i.e.* it carries food, oxygen, corbon dioxide and urea to the desired parts in the body. It also carries the protective corpuscles to places of infection for engulfing the foreign micro-organisms.

2. Blood Glands. These are spherical masses of red colour on the alimentary canal in the segments 4, 5 and 6. They are considered to produce blood-corpuscles and haemoglobin.

3. Blood-vessels. The blood-vessels are closed tubes in which the blood, with its load of materials needing transport, flows. The arrangement of blood-vessels in the first thirteen segments is considerably different from that in the rest of the body. It is consequently essential to describe the blood-vessels in two lots :

(a) Arrangement of Blood-vessels behind the Thirteenth Segment. This region of the body has three longitudinal vessels, namely, the **dorsal, ventral** and **subneural.**

(*i*) **Dorsal Vessel.** It is the largest of the three longitudinal vessels. It runs along the mid-dorsal line a little above the alimentary canal and extends from the posterior to the anterior end of the body. Its thick

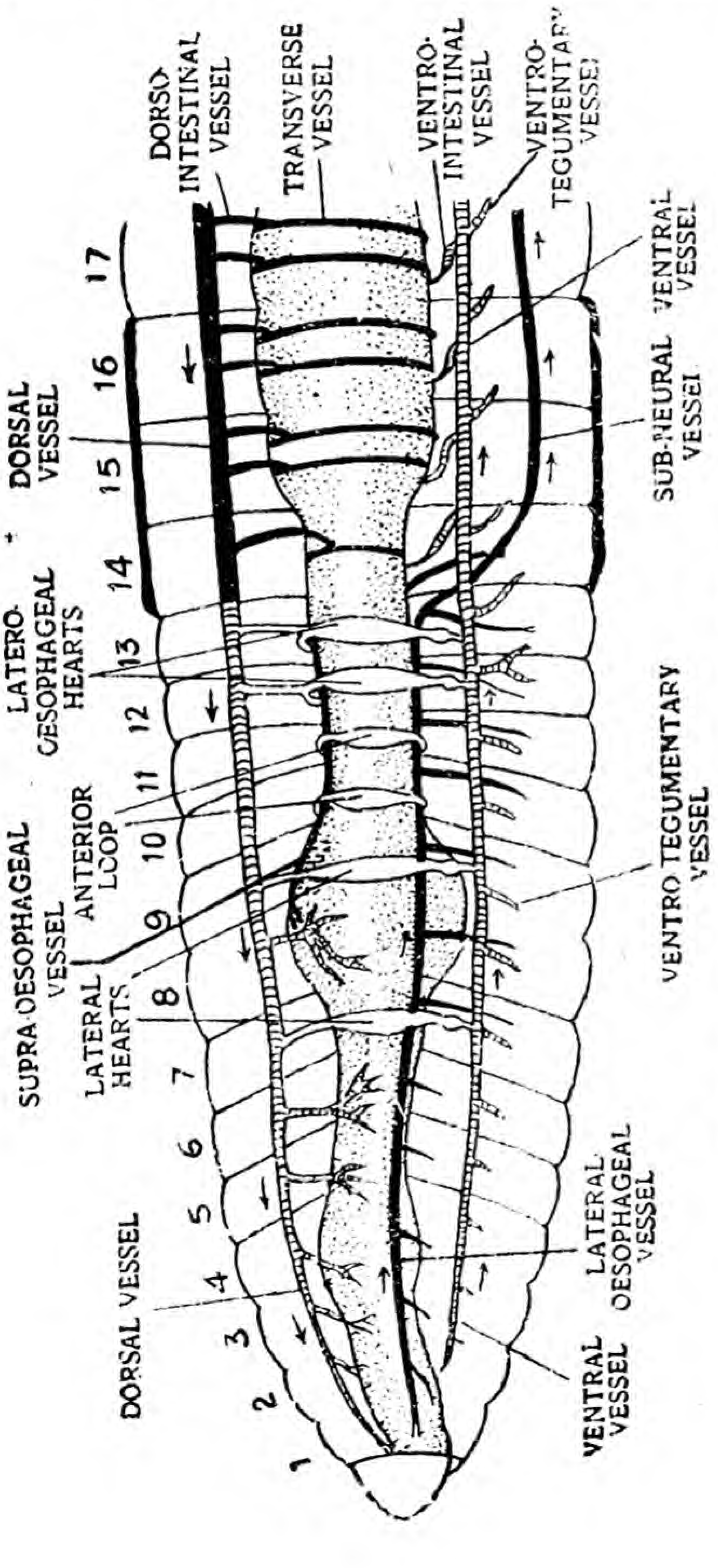


Fig. 11.19. *Pheretima posthuma*—circulatory system

muscular walls undergo rhythmical contractions which pass from behind forwards and drive the blood in the same direction. To prevent the backward flow of the blood, the dorsal vessel is provided with valves of which there is a pair just in front of each septum. The dorsal vessel in this region acts as a collecting channel. In each segment, it receives two pairs of small vessels, the **dorso-intestinal vessels**, and one pair of long vessels, the **commissural vessels**. The dorso-intestinal vessels bring blood from the intestine with the help of an equal number of **transverse vessels** which surround the intestine. The commissural vessels arise ventrally from the subneural vessel, travel upwards along the posterior face of the septum, collect blood from the nephridia and body-wall in the way and open into the dorsal vessel. The dorsal vessel, thus, collect blood from the intestine, nephridia and body-wall.

(*ii*) **Ventral Vessel.** It runs along the median line below the intestine. It also extends throughout the length of the body. It is devoid of valves and the blood flows backwards in it. It acts as the distributing channel in this region. In each segment, it gives off a pair of **ventrotegumentary vessels** to the nephridia and body-wall and an unpaired **ventro-intestinal vessel** to the intestine. The ventral vessel, thus, supplies blood to the intestine, nephridia and body-wall.

(*iii*) **Subneural Vessel.** It is a fine tube running along the median line below the nerve-cord. It extends from the posterior end of the body to the fourteenth segment only. The blood flows backwards in the subneural vessel as in the ventral vessel. Like the dorsal vessel, the subneural vessel also acts as the collecting channel. It receives blood from the nerve-cord and the ventral part of the body-wall. It sends its blood to the dorsal vessel by a pair of commissural vessels in each segment as described earlier.

The dorsal vessel, therefore, collects blood from all parts of the body in the intestinal region and pumps it forwards to the anterior region.

(*b*) **Arrangement of Blood-vessel in the First Thirteen Segments** (Fig.11.19). In this region the dorsal and the ventral vessels are continued as such up to the anterior end, subneural vessel bifurcates into two **lateral oesophageal vessels** and a new vessel, the **supraoesophageal vessel**, is formed on the oesophagus.

(*i*) The **Dorsal Vessel.** It now becomes a distributing vessel. It gives off small branches to the buccal cavity, pharyngeal mass, pharynx, gizzard, oesophagus and pharyngeal nephridia. It sends the rest of its blood to the hearts to be described later. Anteriorly the dorsal vessel reaches the **brain.**

(*ii*) **Ventral Vessel.** It continues to be a distributing vessel here also. It supplies blood to the body-wall, nephridia, spermathecae, seminal vesicles and ovaries by a pair of ventro-tegumentary vessels in each segment. These vessels, however, remain in their own segment and lack septo-nephridial branches.. Anteriorly it reaches the second segment.

(*iii*) **Lateral Oesophageal Vessels.** These are formed, as mentioned above, by the bifurcation of the subneural vessel in the fourteenth segment. They run forwards along the ventro-lateral aspects of the alimentary canal. They collect blood from the body-wall, nephridia, spermathecae, seminal vesicles and ovaries. They send their blood into the supra-oesophageal vessel by two pairs of nonpulsatile circular vessels, the **"anterior loops"** present on the sides of the oesophagus in the tenth and eleventh segments.

(*iv*) **Supra-oesophageal Vessel.** It lies on the oesophagus from the ninth to the thirteenth segments. It collects blood from the gizzard and the oesophagus. It also receives blood from the lateral oesophageal vessels by two pairs of **anterior loops** in the tenth and eleventh segments. It sends its blood by short branches to the posterior two pairs of **hearts** situated in the twelfth and thirteenth segments.

4. Hearts. There are four pairs of hearts, a pair in each of the seventh, ninth, twelfth and thirteenth segments. The anterior two pairs of hearts receive blood from the dorsal vessel only and are called the lateral hearts. The two posterior pairs of hearts receive blood from the dorsal vessel as well as from the supra-oesophageal vessel and are known as **the latero-oesophageal hearts.** All the hearts have muscular pulsatile walls and pump the blood into the ventral vessel by rhythmical contractions. The backward flow of the blood is prevented by valves present in the hearts (Fig. 11.20).

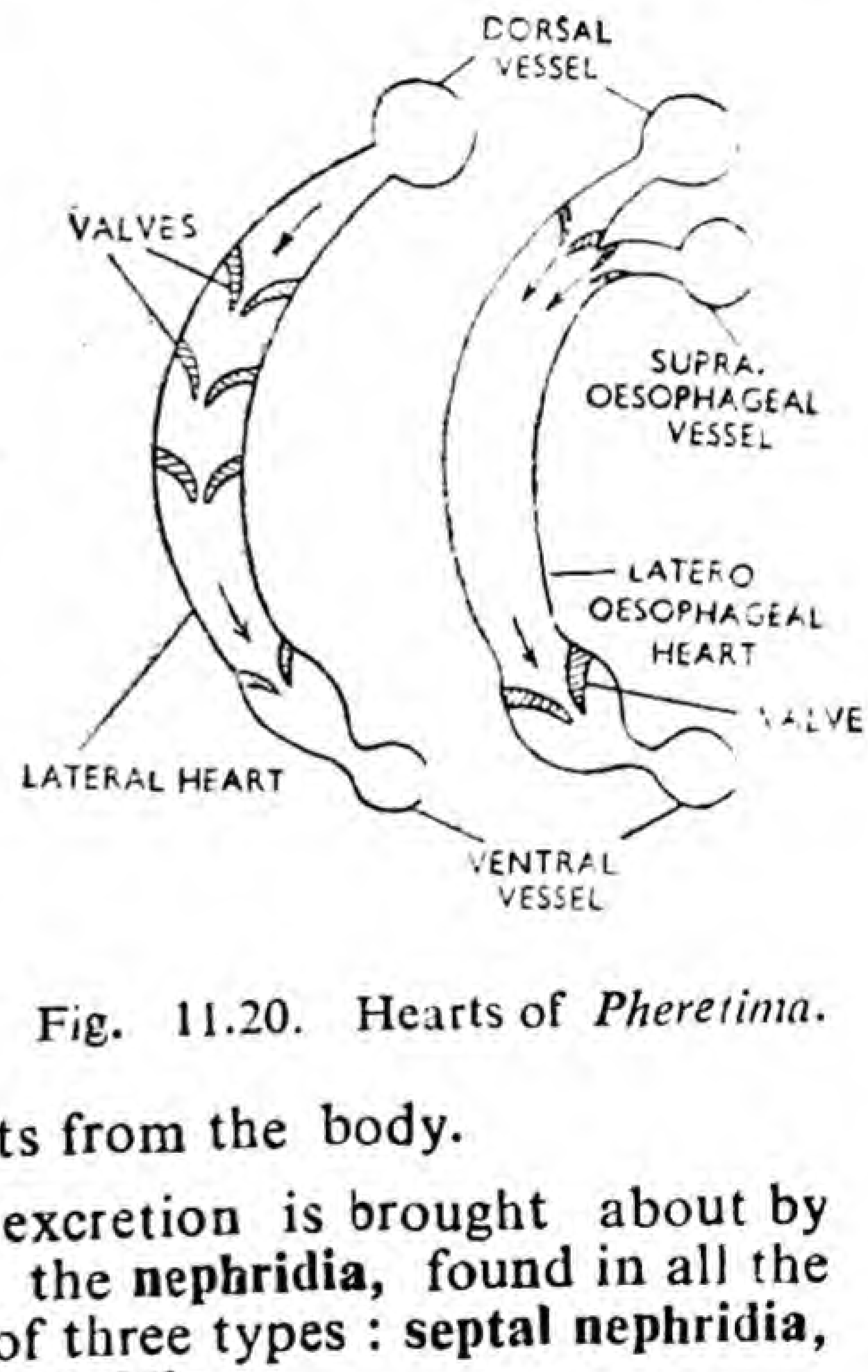


Fig. 11.20. Hearts of *Pheretima*.

Excretory System (Figs. 11.21 and 11.22).

The excretory system serves to eliminate the nitrogenous waste products from the body.

Excretory Organs. In earthworm, excretion is brought about by innumerable microscopic, coiled tubules, the **nephridia,** found in all the segments except the first two. They are of three types : **septal nephridia, integumentary nephridia** and **pharyngeal nephridia.**

(*i*) **Septal Nephridium.** A septal nephridium has 3 regions : **funnel, body** and **terminal duct**. The funnel forms the inner end of the nephridium and has a ciliated margin. It communicates with the coelom by a slit-like aperture, the **nephrostome**. It leads into a short, narrow **ciliated tube** which enters the body of the nephridium. The body consists of short **straight lobe** and a long **spirally twisted loop**. The twisted loop is more than twice as long as the straight lobe, and has two limbs : a proximal and a distal, spirally coiled round each other. The ciliated tube from

the funnel enters the proximal limb of the twisted loop and after taking several turns in the body of the nephridium, leaves the proximal limb as the terminal nephridial duct. The latter is ciliated internally and drains out the waste material from the nephridium.

The septal nephridia are attached to the anterior and posterior faces of all the septa behind the segment 15. They are arranged in two rows

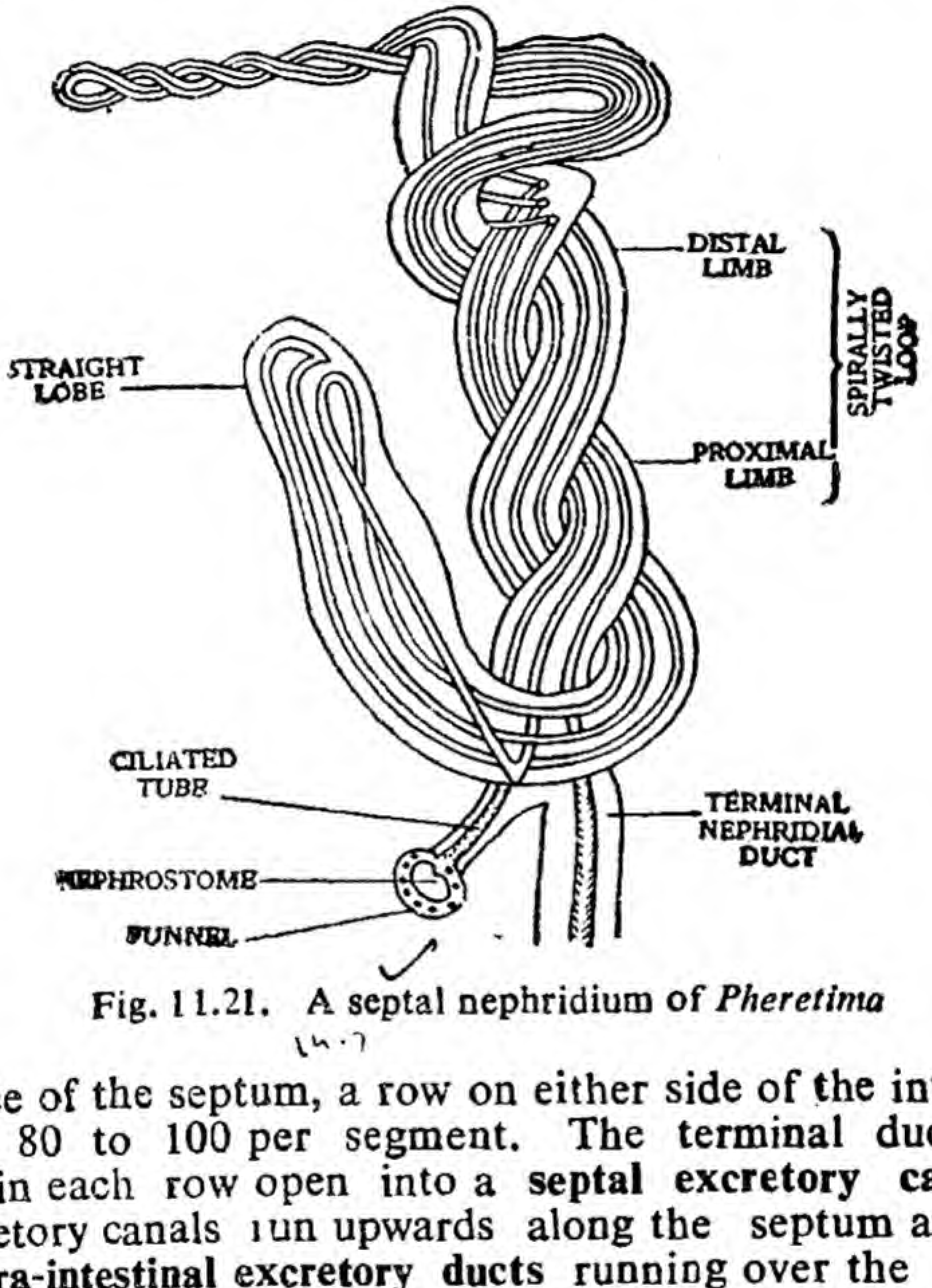


Fig. 11.21. A septal nephridium of *Pheretima*

on each face of the septum, a row on either side of the intestine. They vary from 80 to 100 per segment. The terminal ducts of all the nephridia in each row open into a **septal excretory canal.** The two septal excretory canals run upwards along the septum and open into a pair of **supra-intestinal excretory ducts** running over the intestine from the fifteenth segment to the hind end of the body. Each duct opens into the intestine by a minute ductule in each segment. Since the septal nephridia open into the gut, they are described as **enteronephric.**

(*ii*) **Integumentary Nephridia**. These are attached to the inner surface of the integument or body-wall. They occur in all the segments except the first two. They vary from 200 to 250 per segment. They are said to form "**forests**" in the three clitellar segments where their number is about ten times the number in other segments. The integumentary nephridium is less then half the size of the septal nephridium. It is closed internally as it lacks the nephrostome. Its terminal duct leads directly to the exterior by a fine aperture, the **nephridiopore.** The integumentary nephridia are, therefore, called **exonephric or ectonephric.**

(iii) **PharyngealNephridia.** These are found in the fourth, fifth and sixth segments as three bunches on each side of the alimentary canal. They are as large as the septal nephridia. They are also closed internally. The terminal ducts of all the nephridia of one bunch unite to form a common duct. Three pairs of common ducts are formed in this manner.

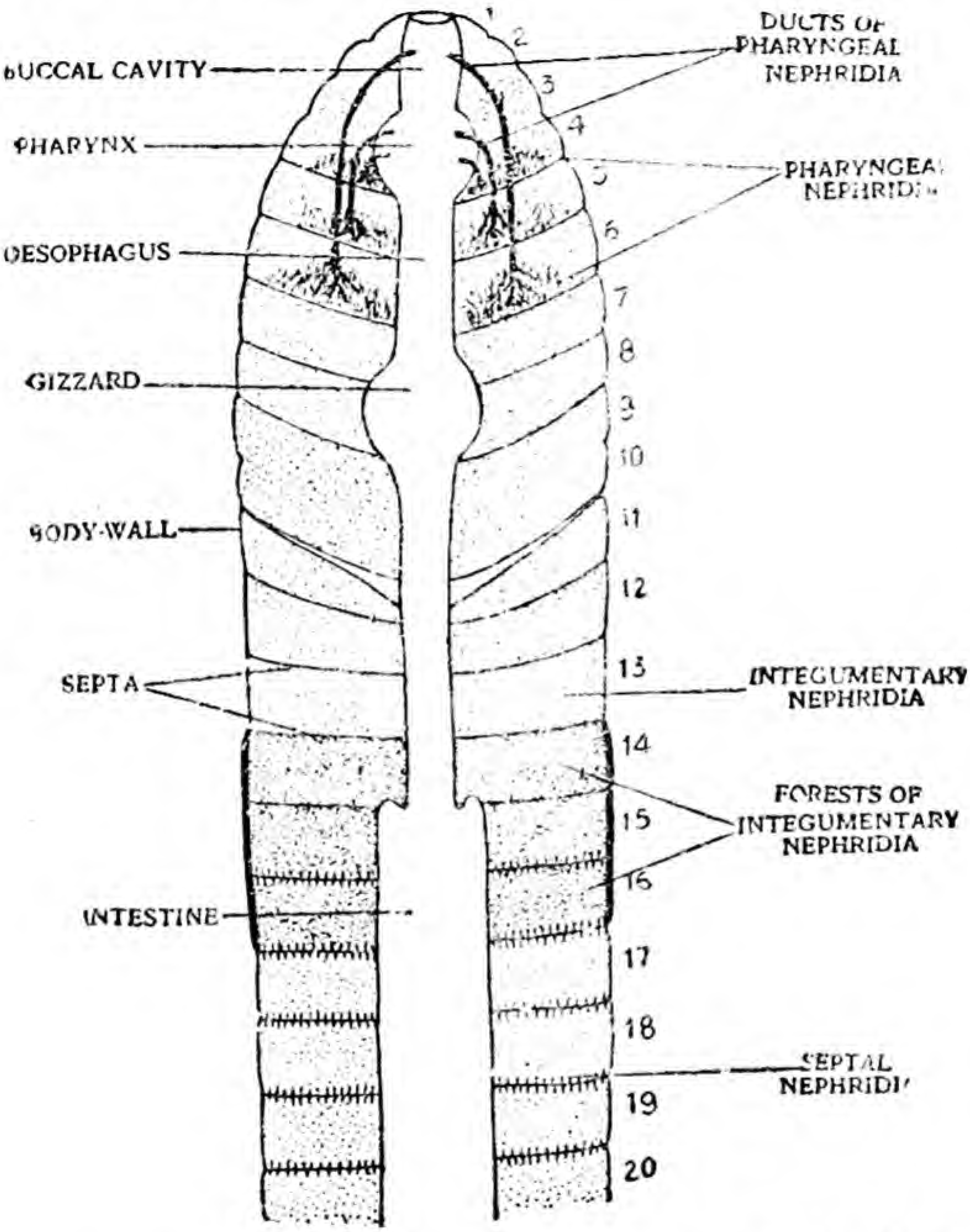


Fig. 11.22. *Pheretima posthuma*—general plan of the distribution of nephridia

The pair of common ducts from the nephridia of the sixth segment open into the buccal cavity while the common ducts of the nephridial bunches of the fourth and fifth segments open into the pharynx. The pharyngeal nephridia are, thus, also enteronephric like the septal nephridia.

Pheretima, thus, possesses two types of nephridial system, viz., **enteronephric system** that includes the septal and pharyngeal nephridia and the **exonephric system** which comprises the integumentary nephridia.

Physiology of Excretion. The nephridial tube has a glandular epithelium which is profusely supplied with blood. The epithelial cells extract waste material, chiefly urea, from the blood. The waste material travels from the body of the nephridium to its terminal duct which discharges it either directly to the exterior or into the alimentary canal. The septal nephridia also receive coelomic fluid with its load of waste products through nephrostomes and convey it into the alimentary canal for removal through the anus. While the coelomic fluid is passing through the nephridia, its useful constituents are taken up by the glandular cells of the nephiridium and conveyed into the blood-capillaries. This process is called **selective resorption.** The fact that the fluid, *i.e.* urine, reaching the nephridiopore is hypotonic to that in the beginning of the nephridium shows that resorption occurs. The elimination of nitrogenous wastes through the gut is an adaptation for conserving water by its reabsorption into the blood.

Some excretory matter is got rid of with the coelomic fluid that passes out through the dorsal pores.

Reproductive System (Fig. 11.23)

The reproductive sytem is concerned with the production of off-spring.

There is only sexual reproduction in earthworm. The animal is hermaphrodite. Self-fertilization, however, does not occur because the testes and ovaries mature at different times. The testes ripen earlier. This condition, called **protandry**, makes cross-fertilization necessary. Hermaphroditism, thus, seems to be of no use to the earthworm. It, however, increases the rate of reproduction as all the earthworms are capable of laying eggs whereas in the unisexual animals only the females or 50% of the population produce eggs.

Male Reproductive System. The male reproductive organs of earthworm are two pairs of testes. They are minute, whitish, palmate bodies situated in the tenth and eleventh segments below the stomach on the sides of the nerve-cord. Each testis consists of a few finger-like processes projecting backwards from a compact base. The processes float in a fluid round them and contain rounded cells, the **spermatogonia.** Each pair of testes is enclosed in a thin walled fluid-filled bag, the **testis-sac.** There are, thus, two testis sacs and they lie one behind the other in the tenth and eleventh segments. The posterior testis-sac is larger than the anterior one. Both the sacs are the shut off portions of the coelom. There are two pairs of large white structures, the **seminal vesicles**, situated in the eleventh and twelfth segments. The seminal vesicles of the eleventh segment are enclosed in the testis-sac of the same segment and communicate in front with the testis-sac of the tenth segment. The seminal vesicles of the twelfth segment are uncovered and communicate in front with the testis sac of the eleventh segment. The seminal vesicles develop as outgrowths of the septa and are, therefore, also called the **septal pouches.** Situated close behind the testes and enclosed in the testis-sacs are two pairs of large ciliated funnels known

as the **spermiducal funnels.** Of these, one pair lies in the tenth segment and the other in the eleventh segment. Each spermiducal funnel leads

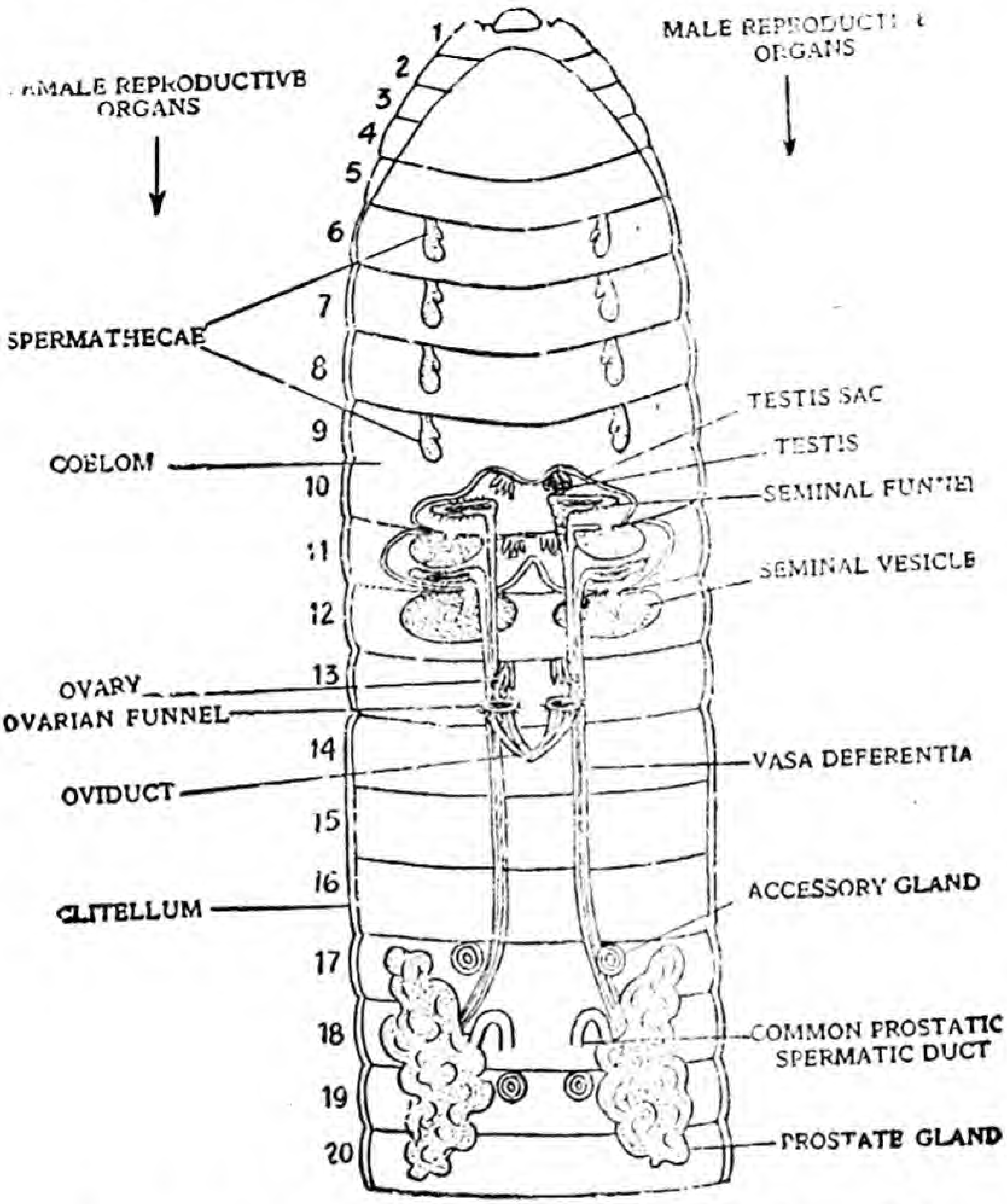


Fig. 11.23. *Pheretima posthuma*—reproductive system

posteriorly into a fine ciliated duct, the **vas deferens.** The vasa deferentia run backwards along the ventral body-wall. The two vasa deferentia of the same side travel close together and meet a short prostatic duct of that side in the eighteenth segment. Here, the three ducts get enclosed in a common muscular sheath to form a **common prostatic and spermatic duct.** Inside the sheath the three ducts remain separate. The two common prostatic and spermatic ducts open to the exterior on the ventral side of the eighteenth segment by the **male genital apertures.** Each male genital aperture, in reality, consists of three apertures, a large aperture of the prostatic duct and two smaller apertures of the vasa deferentia.

Associated with the male reproductive system are found the **prostate and accessory glands.** The prostate glands are a pair of large, flat, irregular, white bodies lying one on each side of the intestine. They

extend from the sixteenth or seventeenth segment to the twentieth or twenty-first segment. In the eighteenth segment each gland gives off on the inner side a short **prostatic duct** which gets enclosed in a muscular sheath along with the vasa deferentia as described above. The function of the prostate glands is not known. The accessory glands are two pairs of rounded masses lying on the ventral body-wall in the seventeenth and ninteenth segments just internal to the prostate glands. They open to the exterior by a number of ducts on the genital papillae situated on the seventeenth and ninteenth segments. Their secretion is thought to assist in keeping the two worms together during copulation.

The testes shed spermatogonia into the testis-sacs whence they pass into the seminal vesicles where they develop into spermatozoa by an elaborate process of **spermatogenesis**. The spermatozoa come back into the testis-sacs and find their way into the spermiducal funnels. From here they travel backwards through the vasa deferentia and are finally shed into the spermathecae of another worm during copulation (to be described later).

Female Reproductive System. The female reproductive organs are a pair of ovaries. They are situated in the thirteenth segment, one on either side of the nerve-cord, attached to the posterior face of the septum between the twelfth and thirteenth segments. Each ovary, like the testis, is palmate. It consists of a large number of finger-like processes arising from a compact base by which it is attached. The processes float in the coelomic fluid and contain rows of ova in various stages of development. Lying immediately behind each ovary is a broad funnel with folded and ciliated margin. This is called the **oviducal funnel**. It leads into a short tube, the **oviduct**, with ciliated lining. The oviducts pierce the septum between the thirteenth and fourteenth segments and converge to meet in the middle line. Then they open to the exterior by a common median aperture, the **female genital aperture,** on the ventral side of the fourteenth segment. The ovaries produce ova by an elaborate process of oogenesis. The mature ova shed from the ovaries are received by the oviducal funnels whence they are passed into the ootheca (to be described later) through the oviducts.

There are four pairs of **spermathecae**, situated a pair in each of the sixth, seventh, eighth and ninth segments. Each spermatheca (Fig. 11.24)

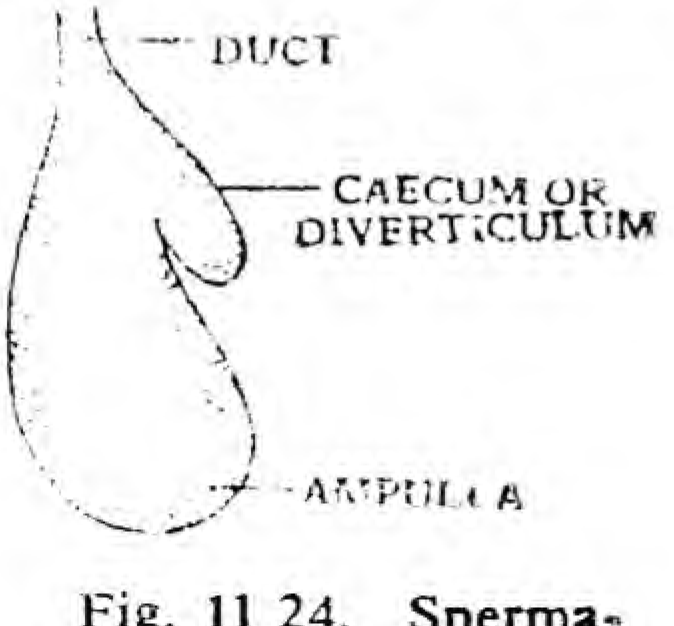


Fig. 11.24. Spermatheca of *Pheretima*

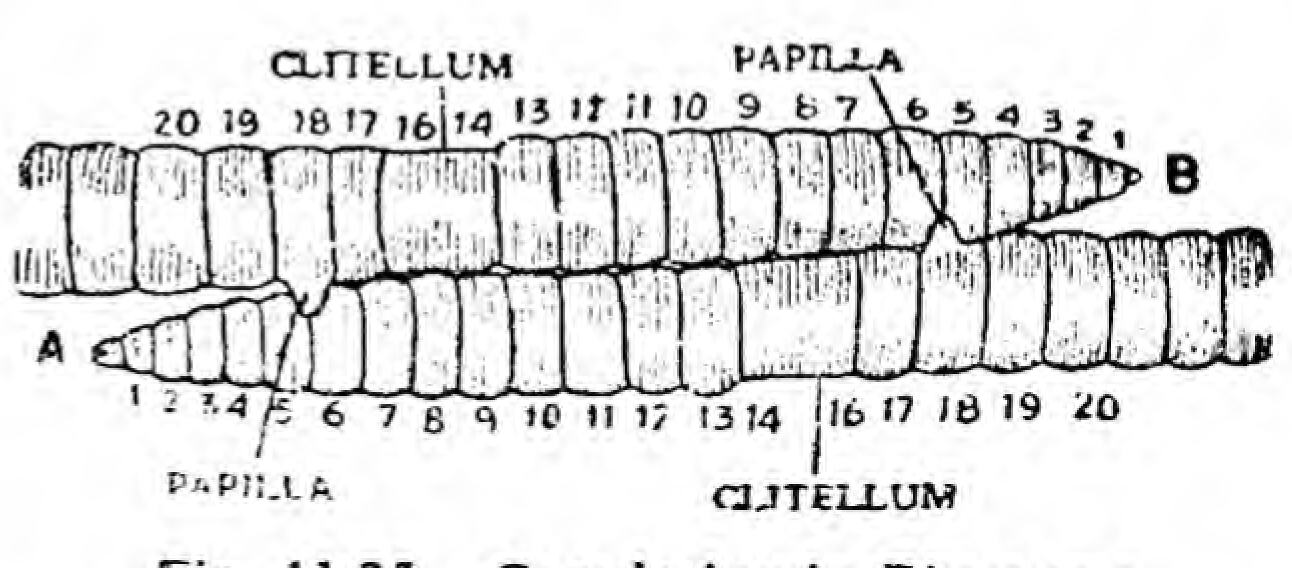


Fig. 11.25. Copulation in *Pheretima*

is a flask-like structure having an expanded **ampulla** and a narrow **neck or duct**. The latter receives a short milky white **diverticulum** or **caecum** on the inner side. The spermathecae serve to store spermatozoa received from another worm during copulation. This function is performed by the diverticulum. The spermathecae open to the exterior by four pairs of **spermathecal pores** which are situated ventro-laterally in the grooves between the fifth and sixth, sixth and seventh, seventh and eighth and eighth and ninth segments.

Copulation. The process of copulation has been studied in *Pheretima communissima*. It occurs on quiet, warm, humid nights or mornings before sunrise during the months of July to October. It lasts for a few hours. Two worms come together by their ventral surfaces in a head-to-tail position so that the male genital apertures [illegible] each worm are opposite the spermathecal pores of the other (Fig. 11.25). The areas of the male genital apertures become raised into small papillae. The papillae of each worm are inserted into the posteriormost pair of the spermathecal pores of the other and the seminal fluid is shed into the spermathecae. The same process is repeated with the remaining spermathecal pores. Then the copulants separate. There is, thus, a reciprocal cross-fertilization in earthworm.

Ootheca Formation. The process of ootheca formation has not been observed in *Pheretima*. It has, however, been followed in some other earthworms like *Eisenia* and *Rhynchelmis*. The oothecae are formed usually during the months of August to October when enough moisture is available in the soil. In the gardens where the soil is wet even at other times of the year, the oothecae may also be laid in April, May and June. Ootheca formation begins some time after the copulation when ovaries have matured.

For the preparation of the ootheca, the gland cells of the clitellum produce a secretion which, on exposure to air, hardens to form a membranous girdle round the clitellum. Several eggs are laid in this girdle from the female genital aperture which the girdle surrounds. The worm now slowly withdraws itself from the girdle. As the girdle passes over the spermathecal pores, sperms are shed into it from the spermathecae. The girdle also receives some albumen from the epidermal glands of the anterior segments. The girdle is finally thrown off. Its ends now close up due to their own elasticity and a somewhat oval ootheca (Fig. 11.26) is formed. The ootheca is deposited by the worm in the earth.

Several oothecae are formed after each mating as the sperms stored in the spermathecae do not pass out all at one time.

Fertilization and development occur inside the ootheca. All the eggs in the ootheca may be fertilized but, as a rule, only one zygote completes its development to produce a new worm. The remaining ova and the albumen serve as food for the developing embryo. The young worm is like the adult so that there is no metamorphosis.

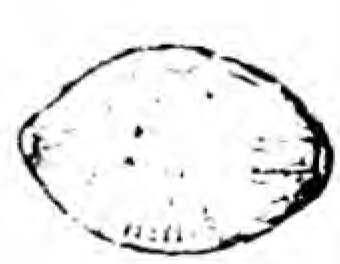


Fig. 11.26. Ootheca

Economic importance

The earthworms, apparently tiny and insignificant creatures, are of a great value to mankind. They work both for and against the human interest.

I. The earthworms are beneficial in the following ways—

1. They improve the soil. This is done in many ways :

(*i*) The soil is made porous by burrowing into it. The porous soil allows better aeration, quick absorption of water and easy penetration of roots.

(*ii*) The worms bring the fresh subsoil to the surface in a finely divided form. Darwin estimated that the earthworms bring to the surface about 5 mm. thick layer of new earth in a year This new finely divided soil forms an ideal medium for the germination of seeds.

(*iii*) Waste matter and faeces thrown out by worms have a good deal of manurial value. The faeces has more nitrate, calcium, magnesium, potassium and phosphorus than the soil from which it is derived.

(*iv*) Earthworms drag leaf fragments down into their burrows and, thus, add organic matter to the soil. This organic matter forms humus.

(*v*) The worms reduce both acidity and alkalinity of the soil, thus creating optimum conditions for plant growth.

2. They serve as food for useful animals. The earthworms are fed upon by frogs, toads, birds, etc. which are useful to man in certain respects. The earthworms have been and are still eaten by some savages.

3. They are employed in scientific study. The earthworm is studied as a representative of the Annelida by the students of Biology all over the world.

4. They provide livlihood to many. As the earthworms are used in scientific study, many persons are engaged in their trade.

5. They are used as fish bait The earthworms form an excellent bait for catching fishes with hooks.

II. The earthworms are harmful in the following respects :

1. Sometimes they damage the small tender plants by eating them up.

2. They spoil golf grounds where they are required to be killed by sprinkling suitable poisons. These grounds are required to be kept hard but are made soft by burrows of worms.

3. Their burrows on sloping lands promote soil erosion during rainy season.

4. Their burrows in the banks of irrigation channels sometimes cause leakage of water.

5 They also serve as an intermediate host for the parasites of some useful animals, *e g* the tape worm of chickens and nematode of pigs.

On the whole, the earthworm is more beneficial than harmful.

Adaptations

Slender body, pointed anterior end and absence of lateral outgrowths facilitate burrowing in the soil. Mucus secreted by gland cells in the epidermis further helps in this work by binding the walls of the burrow. Habit of taking all sorts of dead organic matter ensures sufficient food everywhere. Fossorial and nocturnal life provides safety from the predators. Thin moist skin ensures proper exchange of gases in the absence of special respiratory organs. Hermaphroditism compensates for the lack of asexual reproduction by increasing the rate of multiplication. All earthworms are capable of laying eggs while in unisexual animals only the females, *i.e.* 50% population, produce eggs. Power of regeneration and a good degree of sensitivity increase the chances of survival.

Classification.

The common Indian earthworm described here comes from the

Phylum :	Annelida	Because of metameric segmentation.
Class :	Oligochaeta	Because of having clitellum and fewer setae and lacking head and parapodia.
Family :	Megascolicidae	Because male pores are behind the clitellum.
Genus :	*Pheretima*	Because the setae occur in a complete ring on almost all segments of the body and the clitellum extends over three (14 to 16) segments.
Species :	*P. posthuma*	Because the genital papillae are on the 17th and 19th segments in line with the male genital pores on the 18th segment.

TEST QUESTIONS

1. What do you know about the habitat of earthworm ? Write brief notes on following activities of this animal.
Burrowing, Locomotion, Breeding, Respiration and Regeneration.

2. Give an account of the external characters of earthworm and show how they are adapted to its mode of life.
Discuss the economic importance of this animal.

3. What is coelom ? Describe the coelom of earthworm and mention how it differs from that of the frog, rabbit and cockroach.

4. Make a neat and labelled sketch of the transverse section of the earthworm through the typhlosolar region.

5. What role does the digestive system play in the life of an animal. Describe this system in *Pheretima*.

6. Give a brief account of the circulatory system of earthworm. How does the blood of this animal differ from that of the frog and rabbit ?

7. What is a nephridium ? Name and describe the various types of nephridia found in *Pheretima*.

8. Give an account of the nervous system of earthworm. What is the function of this system and how is it performed ?

9. What is meant by the term "hermaphrodite animal ?" Give a full account of the reproductive system of any such animal you have studied.

10. Make a labelled diagram showing the reproductive system of earthworm. What is the advantage of being hermaphrodite to the animal ?

11. Describe the processes of copulation and ootheca formation in earthworm. Why doesn't self-fertilization occur in earthworm when it is hermaphrodite ?

12. Write brief notes on the following :—
Metamerism, Typhlosole, Setae, Coelomic fluid, Chloragogen cells and Spermatheca.

CHAPTER 12

Periplaneta americana

(The Cockroach)

Cockroach is studied as an example of insects because it is easily available, harmless to handle and of fairly good size for dissection. Moreover, it exhibits insect structure in a fundamental form as it has undergone little change or specialization since it was evolved.

The cockroaches are typically tropical and subtropical insects but they have reached all parts of the world with the trading ships and have acclimatised themselves well in the new localities. Of the numerous species of cockroaches, two are common in India, namely, *Periplaneta americana* and *Blatta orientalis*. The adults of these species differ from each other in size, colour and wings. *Blatta orientalis* is darker in colour and about 25 mm. long while *Periplaneta americana* is lighter in colour and about 38 mm. long. In *P. americana* wings are present in both the sexes and extend beyond the posterior end of the body. In *B. orientalis* wings are rudimentary in the female and do not reach the hind end of the body in the male. *P. americana* is described here.

Habitat

Periplaneta americana, originally a native of tropical America, is now a cosmopolitan creature. It is usually found at places where there is warmth and food, *e.g.* kitchens, hotels, bakeries, warehouses, grain markets, grocer's shops, fruit stalls, railway wagons, ships, underground drains and the like.

Habits

Cockroach is nocturnal, *i.e.* it comes out to feed at night. It remains hidden in crevices and under various objects during the daytime. Eggs are laid in egg-cases or **oothecae**. It is omnivorous in diet taking all types of animal and vegetable foods. It eats bread, fruits, paper, cloth, leather and dead bodies of animals, even of its own fellows. It finds its food by smell. Cockroach is cursorial, *i.e.* runs very fast. It is often quite difficult to capture a running cockroach. It can fly also but does so very rarely. It is unisexual and oviparous. The young cockroach hatching from the ootheca resembles the adult in structure and mode of life except that it is smaller in size and lacks wings. There is no parental care.

External Characters

The cockroach (Fig. 12.1) has a long, ovoid, dorso-ventrally flattened body with bilateral symmetry and rich-brown colour. It measures about 38 × 12 mm. The entire body is externally covered by hard plates or **sclerites** of **chitin** secreted by the underlying cells. The various sclerites collectively form the exoskeleton which not only protects the body but also provides space for the attachment of muscles. The body is segmented externally and is divisible into three distinct regions : **head thorax** and **abdomen**.

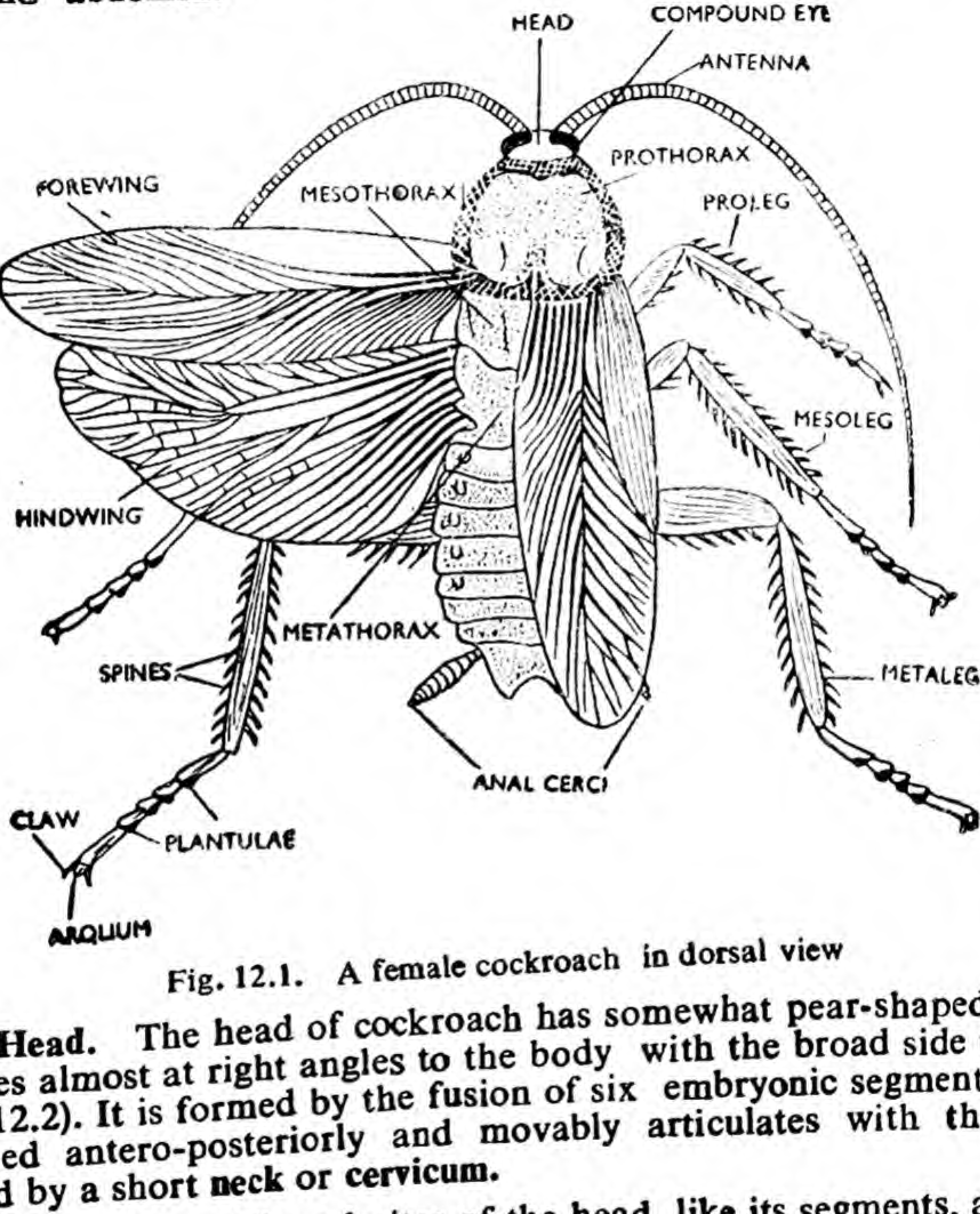


Fig. 12.1. A female cockroach in dorsal view

1. Head. The head of cockroach has somewhat pear-shaped outline and lies almost at right angles to the body with the broad side upwards (Fig. 12.2). It is formed by the fusion of six embryonic segments. It is flattened antero-posteriorly and movably articulates with the thorax behind by a short **neck or cervicum.**

(*a*) **Sclerites.** The sclerites of the head, like its segments, are fused to form a compact **head capsule.** A dark sclerite covers the top of the head and extends down between the eyes. It is called the vertex, In the nymph (young cockroach), the vertex has at its middle a λ-shaped **epicranial suture.** which divides it into two **epicranial plates.** During moulting of the nymphs, the head capsule splits at the epicranial suture. This suture becomes indistinct in the adult cockroach. Below the vertex and covering the head in front are successively the

large **frons**, narrow rectangular **clypeus** and movable **labrum**. Covering the sides of the head and lying below the **compound** eyes are the cheek sclerites or **genae**. At the back of the head capsule is a large aperture, the **occipital** foramen, bordered by an arched sclerite, the **occiput**.

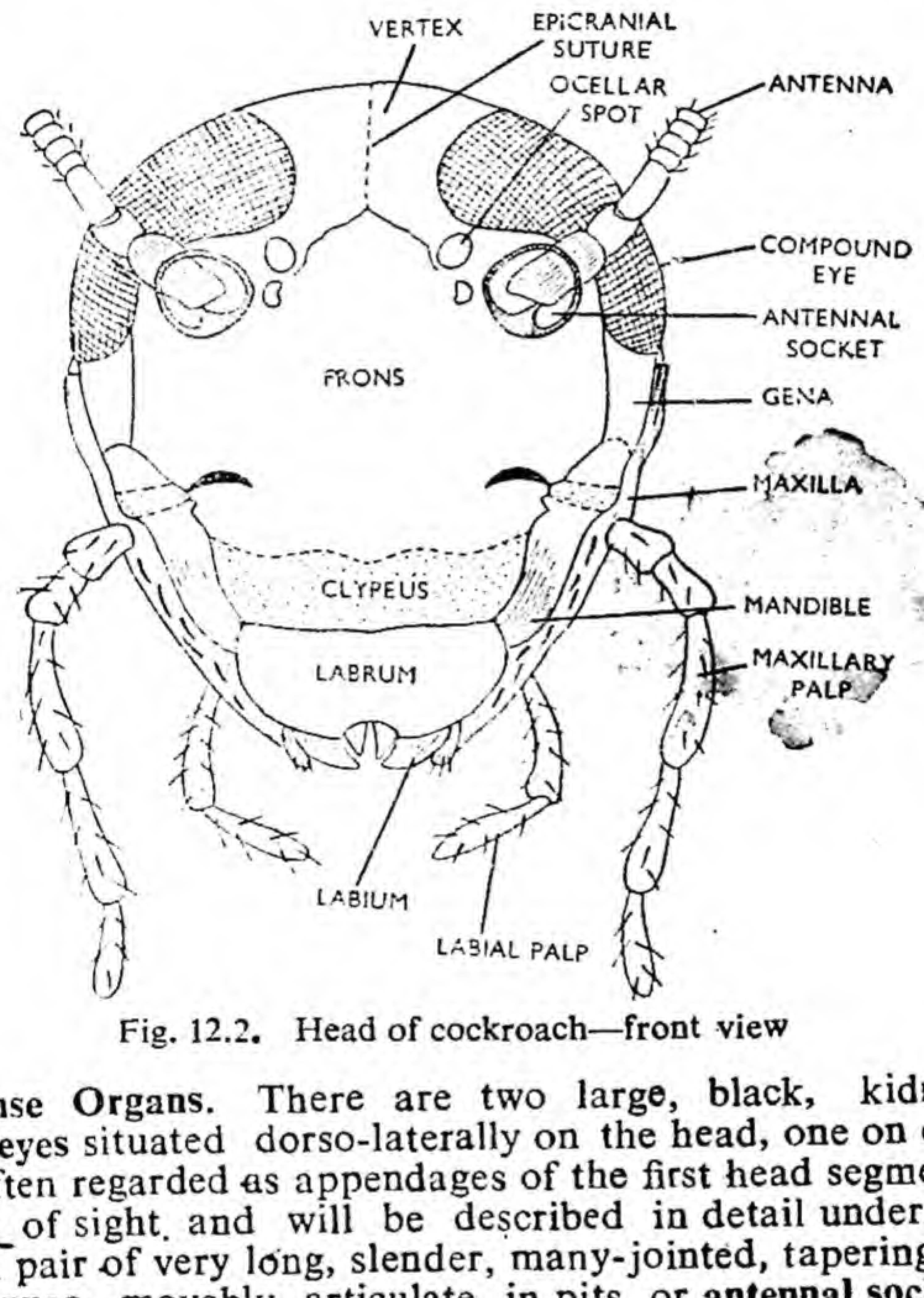


Fig. 12.2. Head of cockroach—front view

(*b*) **Sense Organs.** There are two large, black, kidney-shaped **compound** eyes situated dorso-laterally on the head, one on either side. They are often regarded as appendages of the first head segment. They are organs of sight and will be described in detail under the sense organs. A pair of very long, slender, many-jointed, tapering filaments, called **antennae**, movably articulate in pits or **antennal sockets on the** frons close to the nocthes of the compound eyes. Each antenna has 3 parts : a large basal segment called the **scape**, a short second segment termed the **pedicel** and a long many jointed **flagellum**. The antennae are considered to be modifications of the second head segment. They are the organs of touch and smell. Just above and internal to the base of each antenna, is a minute whitish patch, the **fenestra**. The fenestrae act as the photoreceptors.

(*c*) **Mouth-parts.** These are the movably-articulated appendages surrounding the mouth. They include the **labrum, mandibles, first maxillae, second maxillae** or **labium** and **hypopharynx.** They enclose a space, the **pre-oral cavity.**

(*i*) **Labrum.** The labrum is a vertical rectangular plate movably articulated with the lower margin of the clypeus. It forms the anterior wall of the pre-oral cavity and is also called the upper lip. It serves to hold the food. It is a secondary derivative of the third segment of the head.

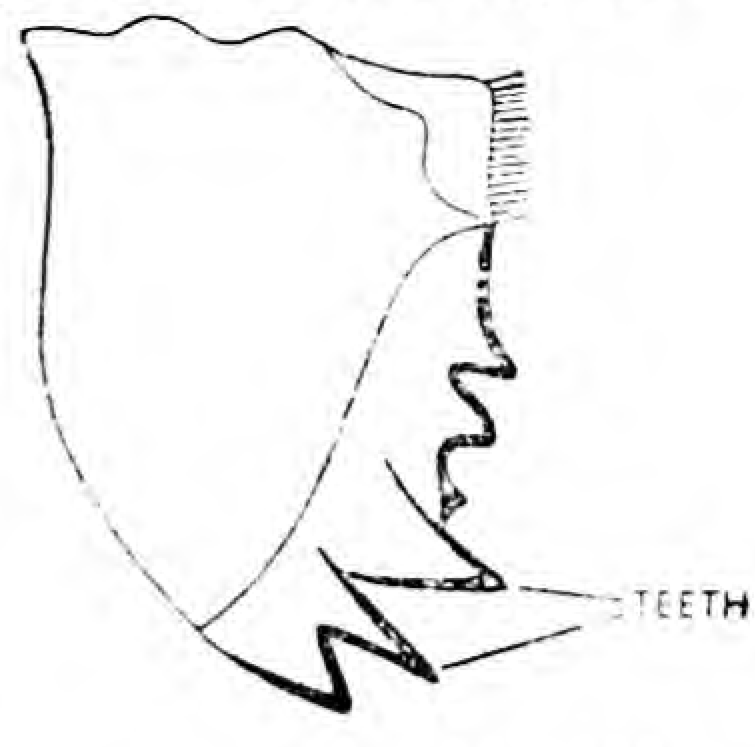


Fig. 12.3. Mandible

(*ii*) **Mandibles.** The mandibles articulate with the genae and lie on the sides of the mouth just behind the labrum. They are thought to be derived from the fourth segment of the head. Each mandible (Fig. 12.3) is a strong heavily chitinised appendage bearing teeth-like projections on its inner edge. The two mandibles serve to cut and masticate the food by working against each other in a horizontal plane.

(*iii*) **First Maxillae.** The first maxillae are situated on the sides of the mouth immediately behind the mandibles. They are regarded as the appendages of the fifth head segment. Each maxilla (Fig. 12 4) is biramous and consists of three parts : the basal **protopodite,** the inner **endopodite,** and the outer **exopodite.** The protopodite is made of two joints : the proximal **cardo** and the distal **stipes,** set at an angle to each other. The exopodite is a long structure arising from the outer side of the distal end of the stipes. It is formed of five joints which bear fine bristles on them. It is also known as the **maxillary palp.** The endopodite is ttached to the distal end of e stipes internal to the max lary palp. It comprises two pieces : the outer hood-like **galea** and the inner claw-like **lacinia.** The latter bears bristles along the inner margin. When not in use, the lacinia fits into a groove of the galea. The maxillae serves to hold by their laciniae and bring it to the mastication. They are also used for cleaning the antennae and prolegs.

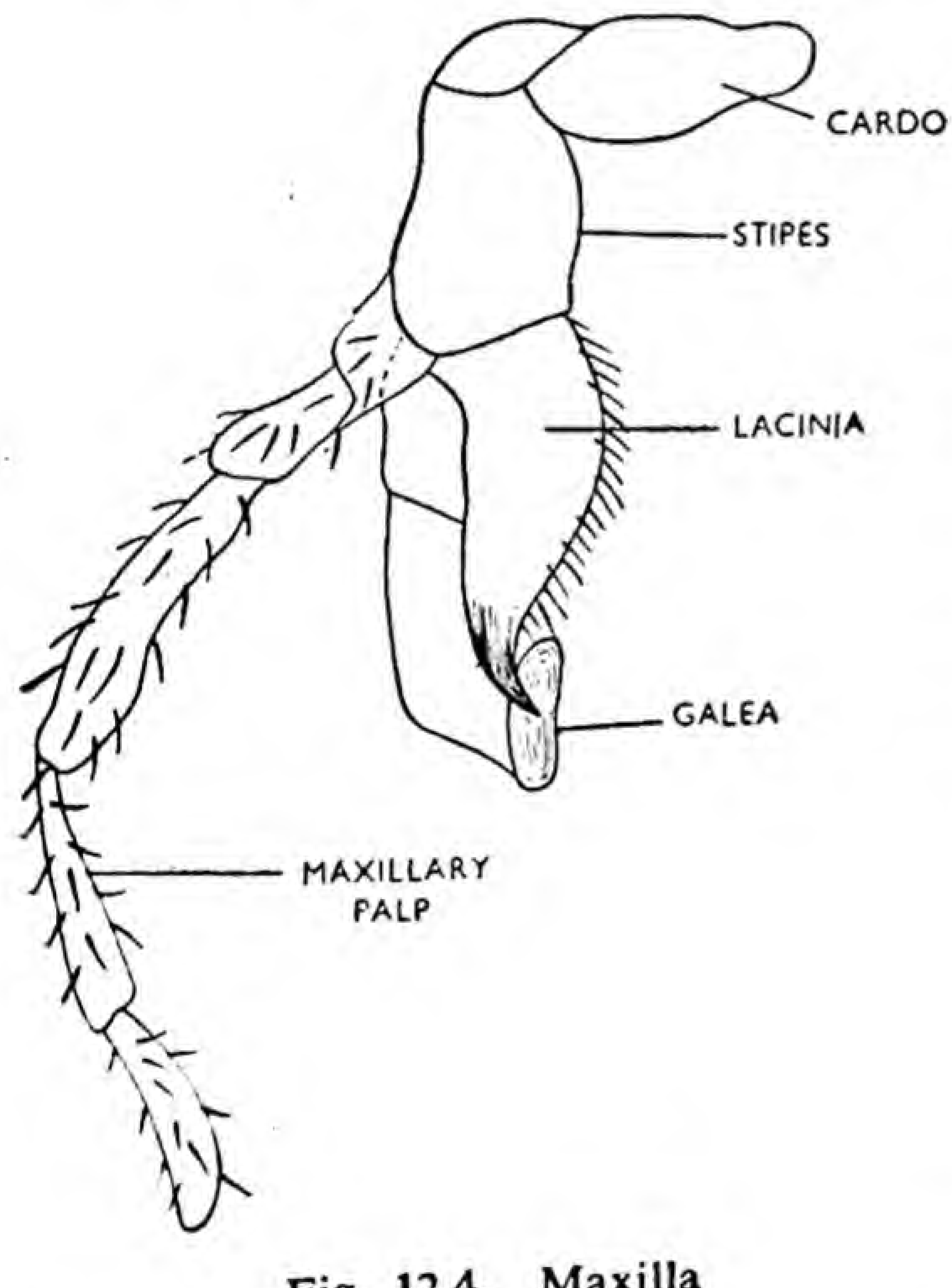


Fig. 12.4. Maxilla

(*iv*) **Second Maxillae.** The second maxillae lie behind the first and have the same basic structure as the first maxillae but their protopodites are fused together along the median line to form a broad plate (Fig. 12.5).

This plate consists of three parts : the upper broad **submentum, the** middle small **mentum** and the lower **prementum.** The endopodites of the second maxillae are almost separate and are together known as the **ligula.** Each half of the ligula comprises two pieces : the inner smaller **glossa** comparable to the lacinia of the first maxilla and the outer larger **paraglossa** comparable to the galea of the first maxilla. The exopodites are also separate. They are called **labial palps.** Each labial palp arises from a short projection, the **palpiger,** of the prementum and consists of three joints. The palps bear bristles and act as sensory organs. They are smaller than the maxillary palps. The glossae and the paraglossae help in holding the food and pushing it into the pre-oral cavity. The second maxillae are the appendages of the sixth head segment. They are together referred to as the **labium or lower lip.**

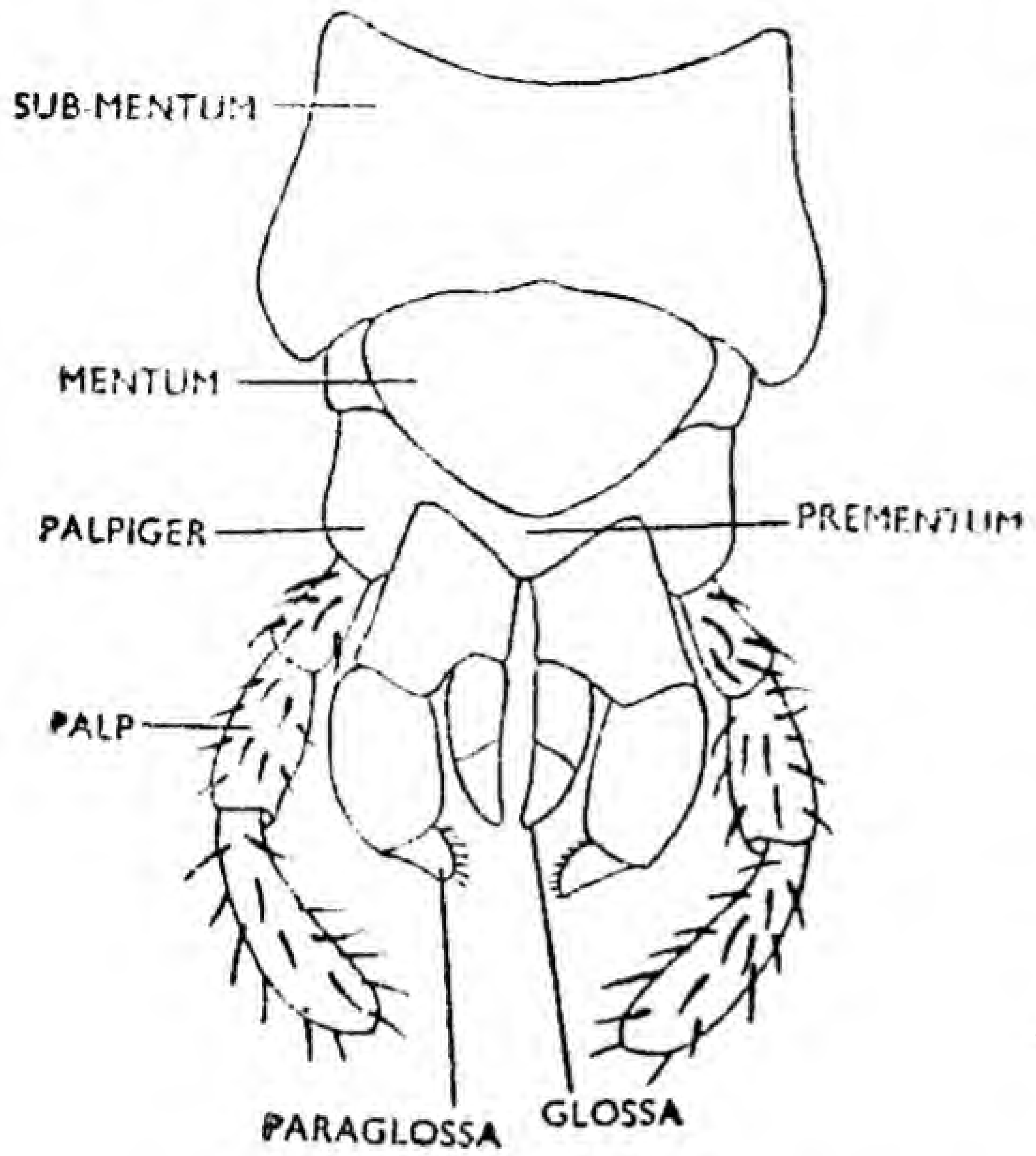


Fig. 12.5. Labium

(*v*) **Hypopharynx.** The hypopharynx, also called the **lingua,** (Fig. 12.6) is a median tongue-like structure hanging in the pre-oral cavity between the first maxillae. It bears the opening of the salivary duct.

The mouth parts of cockroach are used in the mastication of food. They are, therefore, described as the chewing or mandibulate type of mouth-parts.

2. Neck. The neck is a short, slender, flexible tube movably articulating the head with the thorax. It is supported by a few ring-like sclerites. It is merely an extension of an articular membrane and not a segmental region of the body.

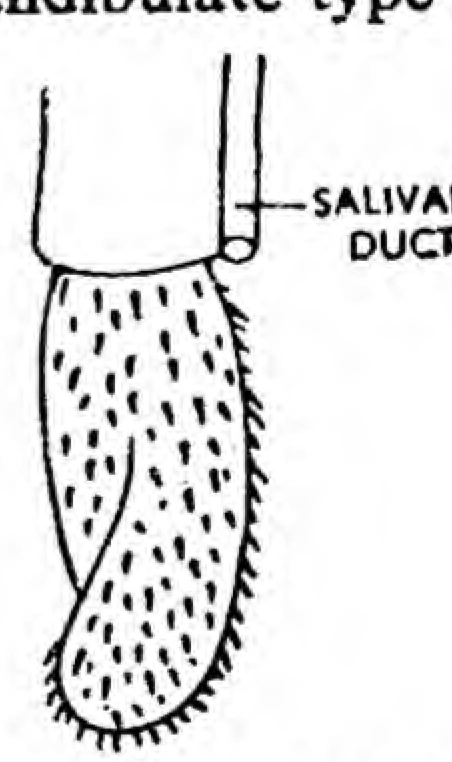


Fig. 12.6. Hypopharynx

3. Thorax. The thorax consists of three segments: the anterior **prothorax,** the middle **mesothorax,** and the last **metathorax.**

(*a*) **Sclerites.** Each segment of the thorax is covered by four sclerites. There is a **tergum** or **notum** on the dorsal side, a **sternum** on the ventral side and a **pleuron** on either lateral side. The tergum of the thorax, called the **protergum** or **pronotum,** is in the form of a large squarish shield which covers the neck and part of the head also. The meso- and metaterga are smaller and rectangular. The sclerites of each segment and also those of the adjacent segments are joined by thin, soft, flexible membranes, the **arthrodial membranes.**

(*b*) **Appendages.** The thorax bears three pairs of jointed walking legs, a pair per segment, and two pairs of wings, a pair on each of the meso- and metathorax.

Legs. All the legs are similar in structure. According to the segment that bears them, they are called the prothoracic, mesothoracic and metathoracic legs or simply **prolegs, mesolegs** and **metalegs.** They articulate with their respective segments between the sternum and the pleuron. Each leg (Fig. 12.7) is formed of five joints arranged in a line. These are called the **coxa, trochanter, femur, tibia** and **tarsus.** The coxa is a short and broad joint. It connects the leg with the thorax. The trochanter is very small and triangular. It is movably articulated with the coxa but is fused with the femur. The latter is a long and narrow joint. It is the strongest part of the leg and bears bristles. The tibia is still longer and slender. It also bears bristles. The tarsus further consist of five small movable joints, the **tarsomeres,** which bear soft pads, the **plantulae,** on the underside. The terminal joint of the tarsus called the **pretarsus,** ends in a pair of sharp curved **claws** between which is a soft hairy pad, the **pulvillus** or **arolium**. The pads afford grip on the smooth and slippery surfaces where claws fail to hold on.

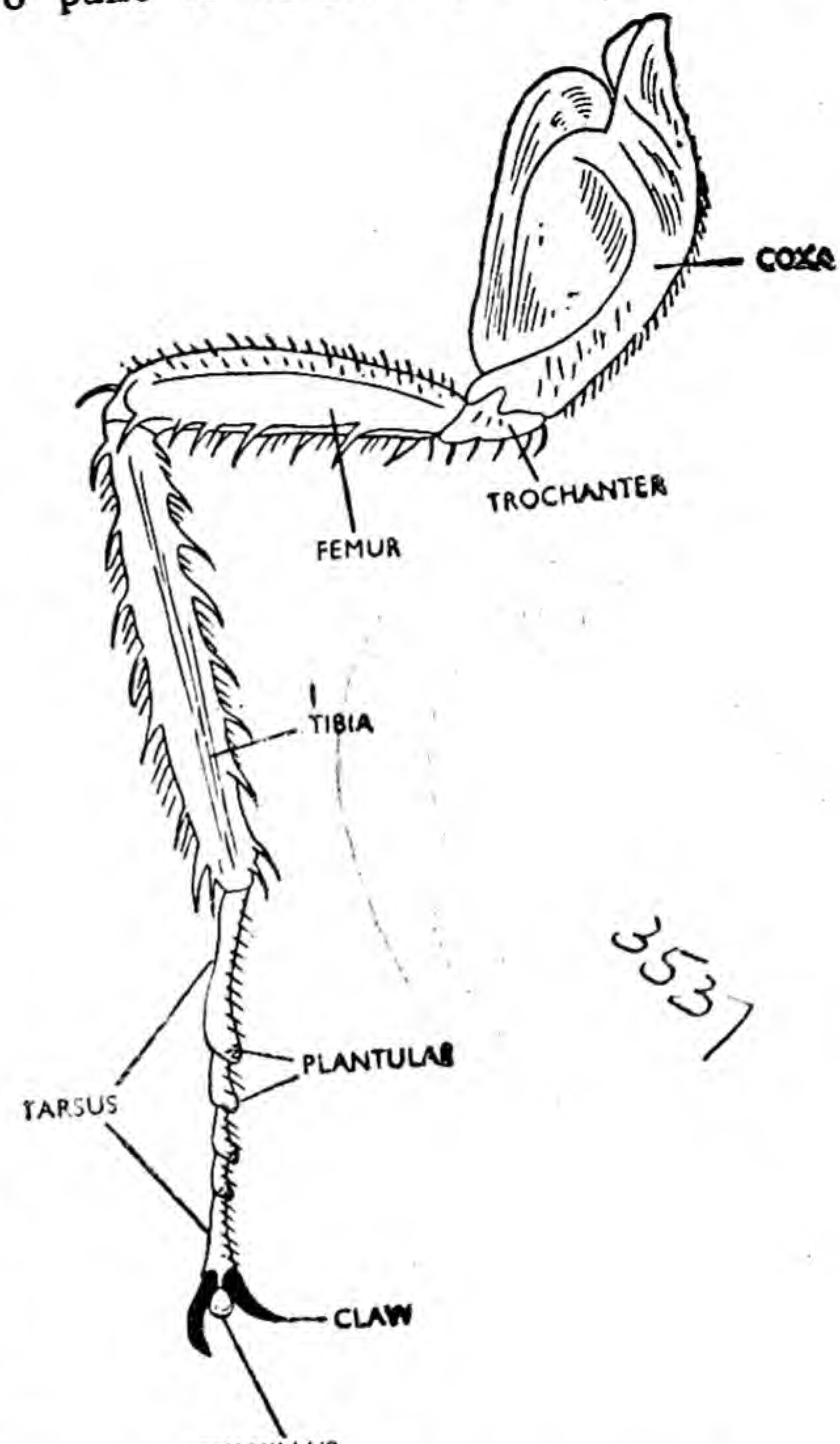


Fig. 12.7. A leg of cockroach

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Wings. The wings, according to their position, are called the mesothoracic and metathoracic wings. They are formed as lateral extensions of the integument or body-wall between the tergum and the pleuron near the anterior end of the segment. When fully formed, the wings consist of two sheets of cuticle fused together and supported by a network of hollow **veins or nervures** (Fig. 12.1). The mesothoracic wings are narrow, thick, opaque and leathery. They are not used in

flight. The[y a]re only protective in function and serve to cover the metathoracic wings when the cockroach is not flying. They are consequently called the wing-covers or **tegmina**. The hind wings are broad, thin, transparent and delicate. They form the real organs of flight They are kept folded like a paper fan beneath the tegmina, when not in use.

4. Abdomen. The abdomen consists of ten segments in the adult, eleven in the embryo. It is broad in front but narrows posteriorly.

(*a*) **Sclerites.** Each segment of the abdomen, like that of the thorax, is covered by four sclerites : a dorsal tergum, a ventral sternum and two lateral pleura. There are ten terga but only nine sterna, the tenth sternum being absent. The eighth tergum in the male and both the eighth and ninth terga in the female are not visible as they are largely overlapped by the seventh tergum. The tenth tergum extends beyond the posterior end of the body as a deeply notched process. In the male, all the nine sterna are visible. In the female only the first seven sterna are visible. The seventh, eighth, and ninth sterna together form a brood pouch. The seventh sternum is produced backwards into a boat-shaped structure, split posteriorly into two parts, the **gynovalvular plates** or **apical lobes**. This forms the floor and the side-walls of the brood pouch. The eighth and ninth sterna are pushed forwards to form the anterior wall and the roof of the brood pouch respectively. The brood pouch has two parts : the anterior **genital chamber** or **gynatrium** and the posterior **oothecal chamber**. Fertilization and formation of a case round the fertilized eggs take place in the blood pouch.

(*b*) **Appendages.** The abdomen bears small appendages at its hind end only. These include a pair of **anal cerci**, a pair of **anal styles** and **gonapophyses** (Fig. 12.8). The cerci are many-jointed tapering appendages arising from the antero-lateral corners of the tenth tergum. They occur in both the sexes. They are actually the appendages of the vestigial eleventh segment. The styles are slender, unjointed processes projecting backwards from the ninth sternum. They occur in the male only. The gonapophyses are very small, irregular, chitinous processes arising from the ninth sternum in the male and from the eighth and ninth sterna in the female. They surround the genital aperture and act as external genital organs.

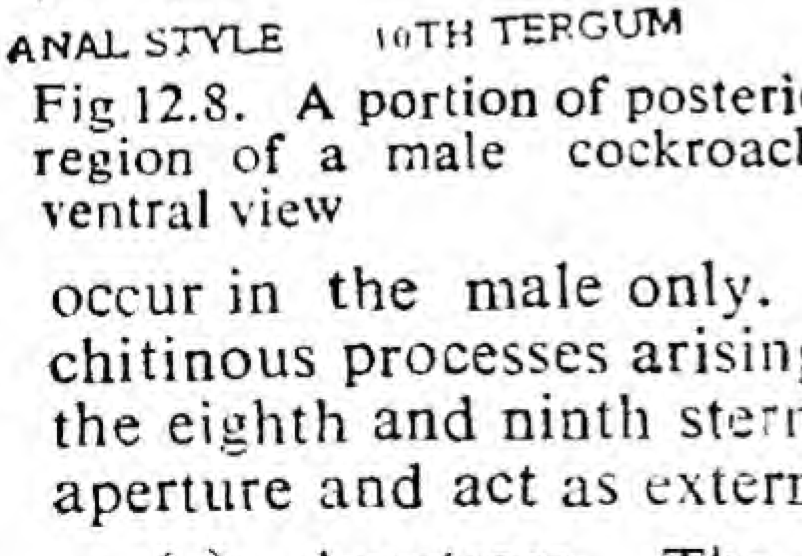


Fig 12.8. A portion of posterior region of a male cockroach-ventral view

(*c*) **Apertures.** The **anus** lies at the hind end of the abdomen between two chitinous plates, the **podical plates** or **paraprocts.** The latter probably represent the remains of the eleventh abdominal segment. The **genital aperture** is situated just below the anus in the male and on the eighth sternum in the female.

(*d*) **Stink Glands.** The intersegmental membrane between the 5th and 6th abdominal terga is depressed on each side to join a stink gland. The stink glands produce a secretion with a characteristic smell.

Spiracles

There are ten pairs of small slit-like apertures, the **stigmata** or **spiracles**, on the lateral sides of the body. Of these, the first two pairs are larger and lie in the thorax while the remaining eight pairs are smaller and lie in the abdomen. The anterior pair of thoracic spiracles are situated in the membrane in front of the mesothorax between bases of the first and second pairs of legs. The posterior pair of thoracic spiracles are placed in front of the metathorax between the bases of the second and third pairs of legs. The first pair of abdominal spiracles are dorsal in position, lying on the lateral margins of the first abdominal tergum. The remaining abdominal spiracles are on the sides of the abdomen, each being located between the two adjacent terga and two adjacent sterna. The walls of the spiracles bear bristles which together form a sort of filter to keep out dust particles or water. The spiracles lead into the respiratory tubes. They are controlled by special muscles which can open or close them as desired.

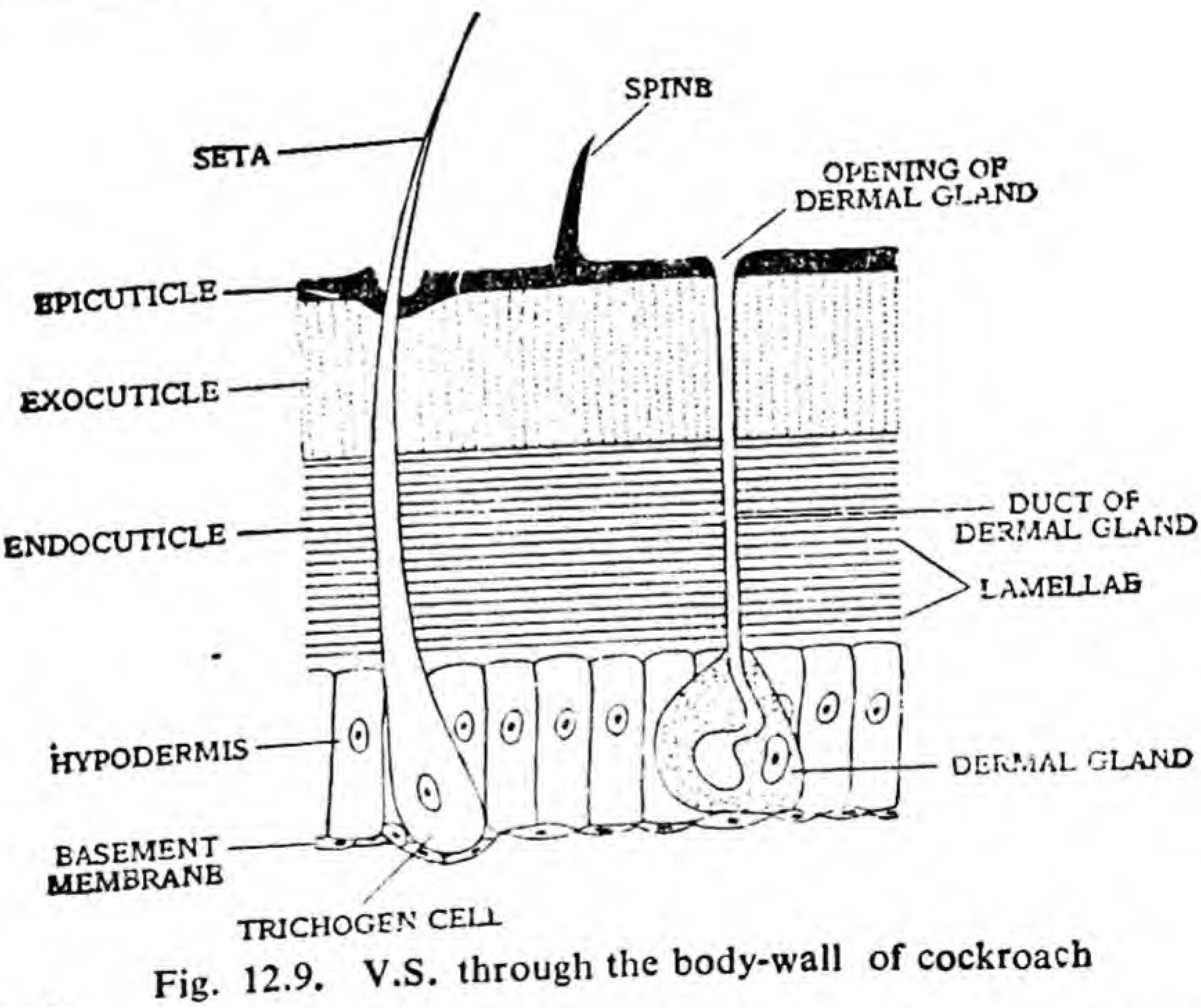


Fig. 12.9. V.S. through the body-wall of cockroach

Body-wall

(*a*) **Structure**. The body-wall consists of three layers: **cuticle, epidermis (Hypodermis)** and **basement membrane** (Fig. 12.9). The cuticle is the outermost layer. It is differentiated into three regions : an outer thin **epicuticle** of waxy nature, a middle thicker **exocuticle** of tough pigmented chitin and an inner much thicker **endocuticle** of soft laminated chitin. The articular membranes lack exocuticle and are, therefore, flexible. The epidermis consists of a single layers of columnar cells which secrete the overlying cuticle. The basement membrane limits the body-wall internally. It has flattened cells in a homogeneous intercellular substance.

The body-wall has many outgrowths including the hair-like movable **setae** and the stouter immovable **spines.**

(*b*) **Functions.** The body-wall forms a protective wrapper for the delicate internal organs. The cuticle checks the loss of water by evaporation and provides a hard surface for the attachment of muscles. Outgrowths of the cuticle act as sensory, feeding, filtering, copulatory and locomotory organs.

Coelom

The true coelom is greatly reduced in cockroach. It is represented by the cavities of the reproductive organs. The space round the internal organs or the perivisceral cavity is full of blood and is called the **haemocoel.** It is an expansion of the blood-vascular system and will be described in that system.

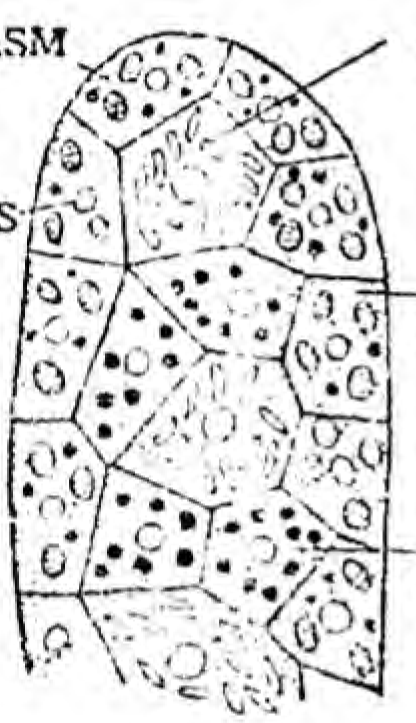


Fig. 12.10. Section of a lobe of fat body

Fat Body or Adipose Tissue

A tissue of large white cells derived from the mesoderm almost completely surrounds the viscera. It is held in place by branching tracheae with which it is supplied. It is called the fat body or adipose tissue (Fig. 12.10). It contains not only fat but also protein and glycogen. It constitutes the reserve food-material. The food is released into the blood for use when required. Certain cells of the adipose tissue contain nitrogenous waste matter in the form of uric acid. Still others harbour symbiotic micro-organisms (bacteroids).

Muscles

Muscles form a considerable part of the body of cockroach. The head and legs are almost completely full of muscles. The muscles are abundant in the thorax also. The abdomen is, however, less muscular. All the body-muscles are **striated** in nature and provide quick movements. This is one of the factors responsible for the remarkable success of the insects. The muscles do not form a uniform layer inside the body-wall as they do in the earthworm. They are arranged in bundles which move particular parts of the body. They are attached to the inner surface of the skeleton unlike the vertebrate muscles which are external to the skeleton. The most conspicuous muscles are those which move the jaws, legs and wings.

Locomotion

Cockroach has a double mode of locomotion, running and flying. It runs on the tarsi (plural of tarsus) of its legs. In the act of walking or running, the prolegs pull the body forwards and the metalegs give it a push from behind. At a time, three legs are kept on the ground and the other three are carried forward. The pro- and metalegs of one side respectively pull and push the body which is supported on the mesoleg of the opposite side. During this action, the other three legs are placed

on the ground a little ahead and the first three legs are carried forwards. By the repetition of this process the animal progresses forwards. The plantulae, pulvilli and claws prevent backslipping by giving a grip over the substratum. The claws function on the soft and rough surface while the pads work on the hard slippery places.

Cockroa h flies by beating the hind-wings with special muscles. They are beaten up and down alternately. The beat is oblique and not vertical. At each downstroke the wings push the air downwards and backwards. This propels the body upwards and forwards. During flight the fore-wings are held at right angles to the body but do not beat. Flight is, however, very rare in cockroach.

Digestive System (Figs. 12.11 and 12.12)

The digestive system serves to digest the food, *i.e.* to prepare it for absorption into the blood so that it becomes available to the body for use in growth, maintenance and production of energy.

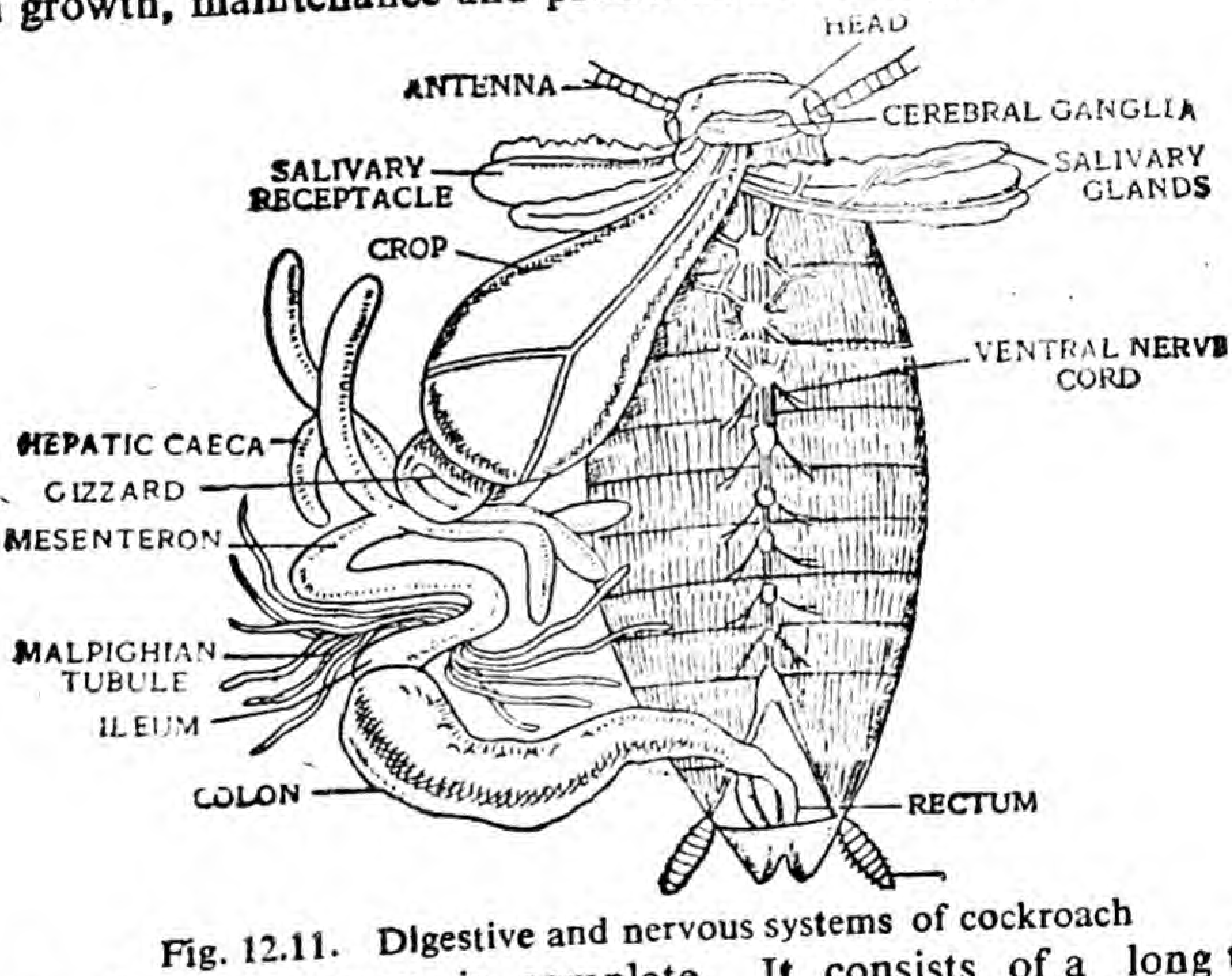


Fig. 12.11. Digestive and nervous systems of cockroach

The digestive system is complete. It consists of a long tube of varying diameter, termed the **alimentary canal**, and some **digestive glands** associated with it.

1. Alimentary Canal. The alimentary canal comprises three regions, namely, the **fore-gut** or **stomodaeum**, the **mid-gut** or **mesenteron** and the **hind-gut** or **proctodaeum**. Of these, the fore- and hind-gut are ectodermal and are lined by cuticle continuous with the exoskeleton. The mid-gut is endodermal and without cuticular lining.

(*i*) **Fore-gut.** The fore-gut consists of the **pre-oral cavity, pharynx, oesophagus, crop and gizzard** or **proventriculus**. The pre-oral cavity is bounded anteriorly by the labrum and clypeus, posteriorly by the labium and laterally by the mandibles and first maxillae. There is a soft chitinous lining on the inner surface of the labrum. This is called

the epipharynx and bears the organs of taste. The hypopharynx hangs into the pre-oral cavity a little in front of the labium. It bears the open-

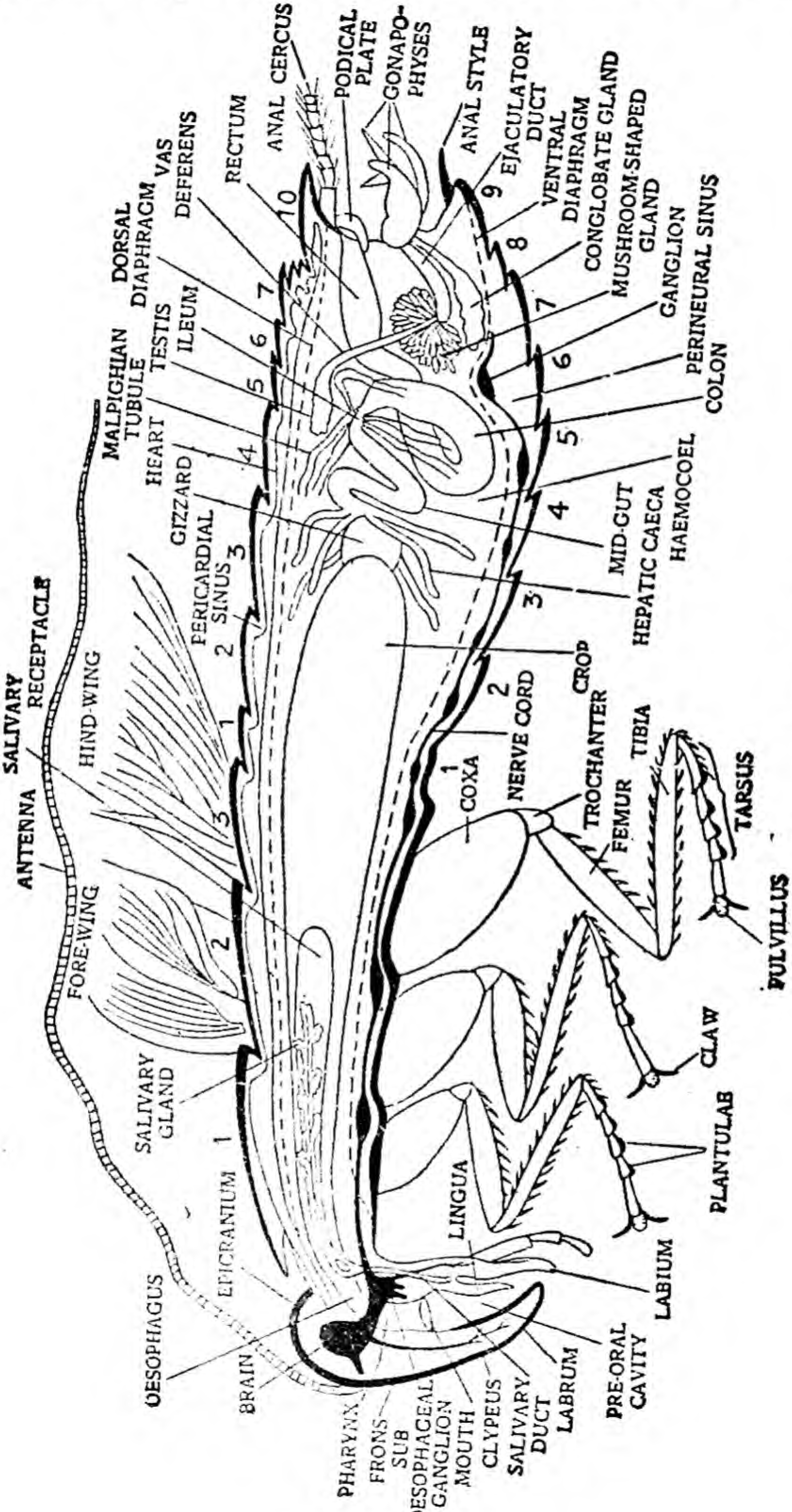


Fig. 12.12. Viscera of cockroach

ing of the salivary duct. The mouth lies on the roof of the pre-oral cavity. The mouth leads into a tubular pharynx which runs vertically upwards and then bends backwards as the oesophagus. The latter passes through the neck and expands to form a large thin-walled sac, the crop, which occupies the whole of the thorax and first two abdominal segments. The crop is followed by a small gizzard with thick muscular walls. Its lumen is considerably reduced by infolding of its wall. The folds bear six hard conical teeth for grinding the food. Behind the teeth, the folds of the gizzard are beset with fine bristles which act as strainer, allowing only well-crushed food to pass on. The end of the gizzard projects into the mid-gut in the form of a funnel.

(*ii*) **Mid-gut.** The mid-gut is a narrow tube lined with tall endodermal cells which are glandular in nature. There are seven or eight blind tubular out-growths, the **hepatic** or **mesenteric caeca**, at the anterior end of the mid-gut. They increase the area of the mid-gut. At the posterior end of the mid-gut is sphincter muscle sometimes called **pyloric valve.** The latter checks the regurgitation of faeces and uric acid from the hind-gut.

(*iii*) **Hind-gut.** The hind-gut consists of a short narrow **ileum**, a long **colon** and a short broad **rectum**. The latter opens out by a slit-like **anus** which lies below the **tenth** tergum between two podical plates. A large number of very fine, yellow, thread-like processes, the **Malpighian tubules**, open in the beginning of the ileum. These tubules are excretory in function.

The wall of the fore-gut consists of a number of layers which, starting from inside, are **cuticle, epithelium, basement membrane, longitudinal muscles, circular muscles and connective tissue.** The midgut and the hind-gut also have the same layers except that the former lacks the cuticle (Fig. 12.20) and the latter has an additional layer of circular muscles between the longitudinal muscles and the basement membrane.

Digestive Glands. The digestive glands of cockroach include the **salivary glands**, the **hepatic caeca** and the **lining of the mid-gut**. There are two pairs of salivary glands, a pair on either side of the crop in the pro- and mesothorax (Figs. 12.11 to 12.13). Between the two glands of each pair lies a sac-like **salivary receptacle**. From the glands of each side arises a duct which unites with its fellow of the opposite side to form a median duct. The two ducts from the two receptacles also join

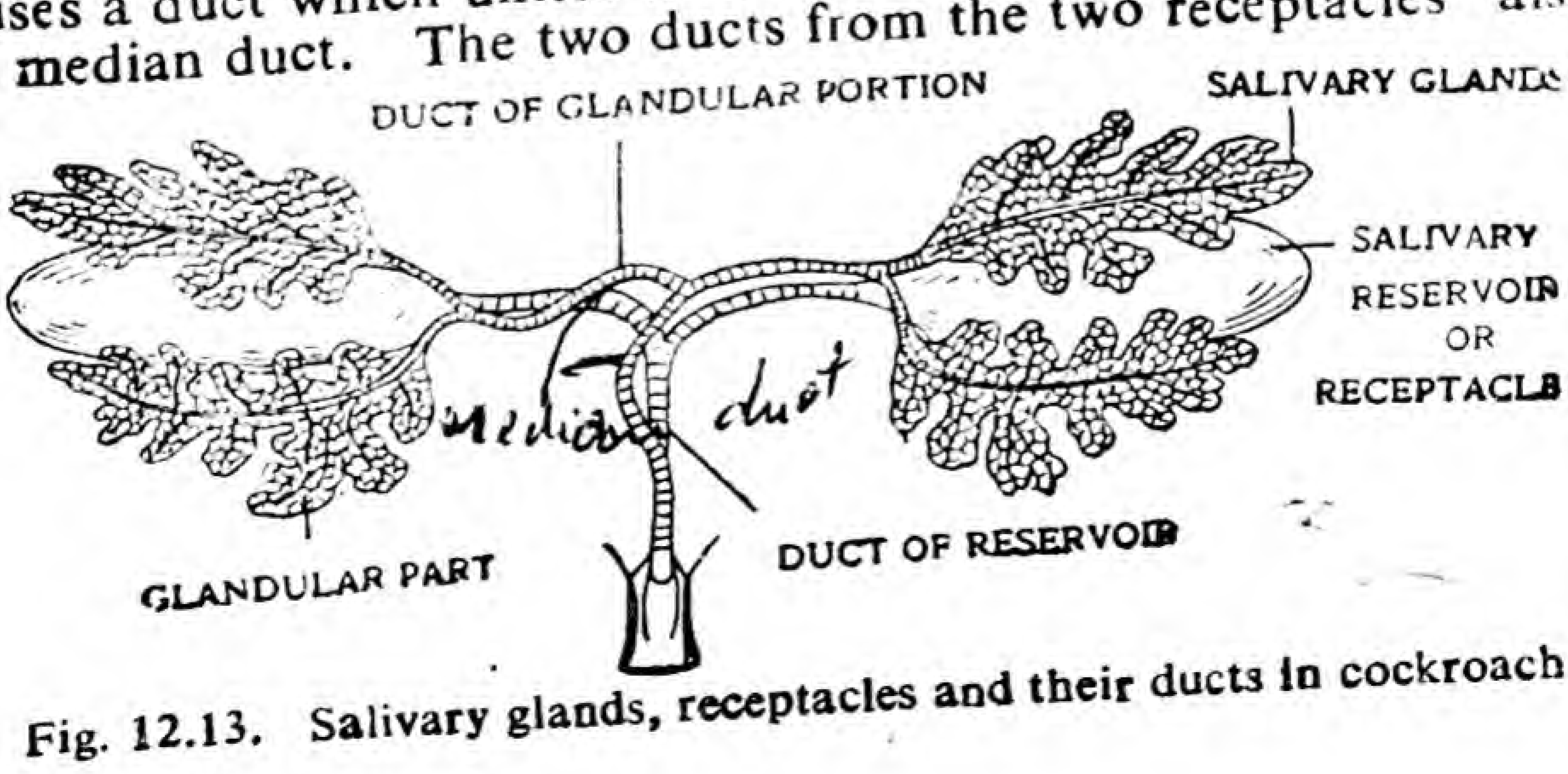


Fig. 12.13. Salivary glands, receptacles and their ducts in cockroach

to form a median duct. The two median ducts unite to form a **common salivary duct** which passes forwards through the neck and opens on the hypopharynx in the pre-oral cavity. The secretion of the salivary glands is neutral and is called **saliva.** It contains a starch-splitting enzyme, **amylase.** The hepatic caeca and the lining of the mid-gut produce a juice which contains many enzymes.

Physiology of Digestive System. The cockroach, as pointed out earlier, is omnivorous. It takes all types of animal and vegetable matter though prefers sugary and starchy substances. The food is located by the sense of smell whose receptors lie on the antennae and palps. It is masticated with teeth of the mandibles. The laciniae and galeae of the maxillae and glossae and paraglossae of the labium hold the food during the act of mastication. The labrum and the labium prevent the loss of food from the jaws. During chewing, the food is mixed with saliva brought into the pre-oral cavity by the common salivary duct. Amylase of the saliva converts starch of the food into sugar. Saliva also moistens the food and the mouth-parts to assist chewing and later swallowing. The food so masticated is pushed by the maxillae and the labium into the pre-oral cavity from where the food enters the mouth and reaches the crop by peristalsis. Digestion of food started in pre-oral cavity by the saliva continues in the crop. Enzymes from the mid-gut also come into the crop through the gizzard for the digestion of some fats and proteins here. In the gizzard the food is further masticated by the chitinous teeth and is then filtered by the bristles. In the mid-gut food meets the secretion from its lining and the hepatic caeca. The secretion contains many enzymes like **proteolytic enzyme** which converts proteins into amino-acids, **lipase** that breaks fats into fatty acids and glycerine and **amylase** which completes the digestion of starch. The digested food is absorbed by the cellular lining of the mid-gut and hepatic caeca.

In the mid-gut a peculiar phenomenon takes place. This is the formation of a **peritrophic membrane** round the food for the protection of the delicate lining of the mid-gut from abrasion by hard indigestible particles in the food. This peritrophic membrane is a thin chitinous tube formed of the secretion from the funnel-like extension of the gizzard round the food. This membrane is fully permeable to both enzymes and digested food. Traces of this membrane are sometimes seen round the faecal pellets.

The indigestible food passes into the mid-gut. Here, especially in the rectum, water is absorbed from the indigestible residue which changes into almost solid faeces. The faeces is temporarily stored in the rectum from where it is passed out at intervals.

The absorbed food is distributed to all parts of the body by the blood. It is partly assimilated and partly stored in the fat body present in the haemocoel.

Respiratory System (Fig. 12.14)

The respiratory system provides oxygen to the body and removes carbon dioxide from it.

Respiratory organs. The system consists of a network of white shining air tubes or **trachea** which communicate with the exterior by ten pairs of

stigmata or spiracles, already described. The tracheae are formed as invagination of the skin and are, thus, ectodermal in nature. Each trachea consists of a single layer of squamous epithelium which secretes a chitinous lining. To prevent collapsing of tracheae, they are further strengthened by a spiral band of chitin. The cuticular lining of the tracheae is shed during moulting of the young cockroach. The stigmata lead into larger tracheae which branch and rebranch to

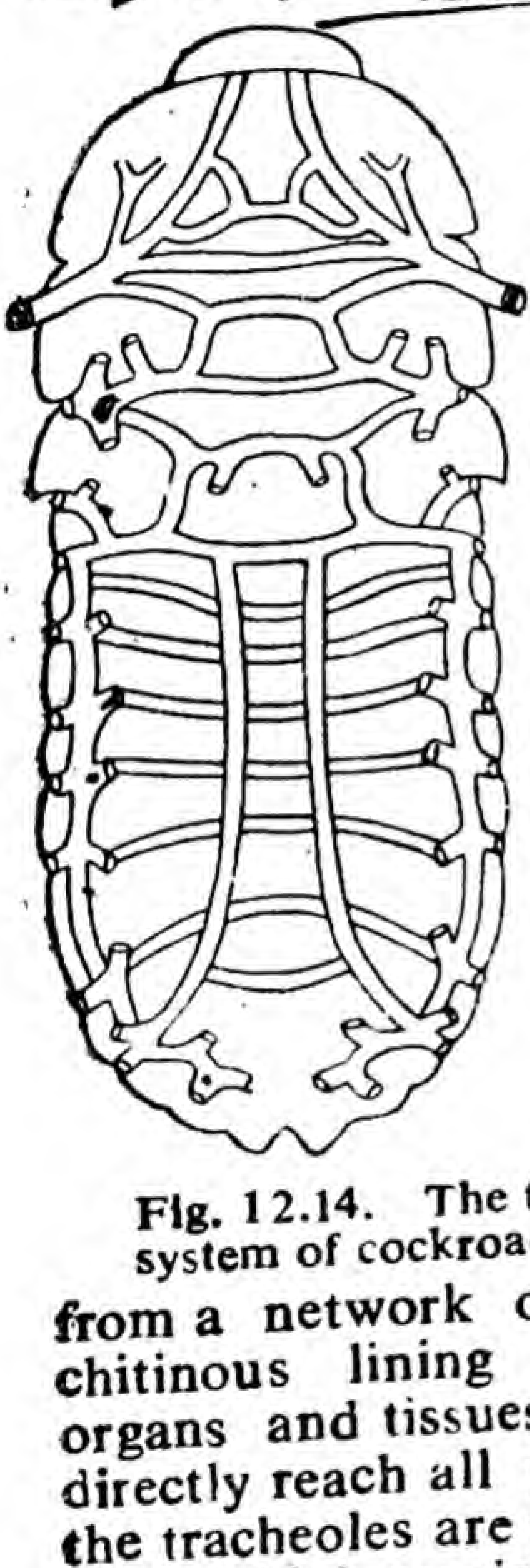


Fig. 12.14. The tracheal system of cockroach

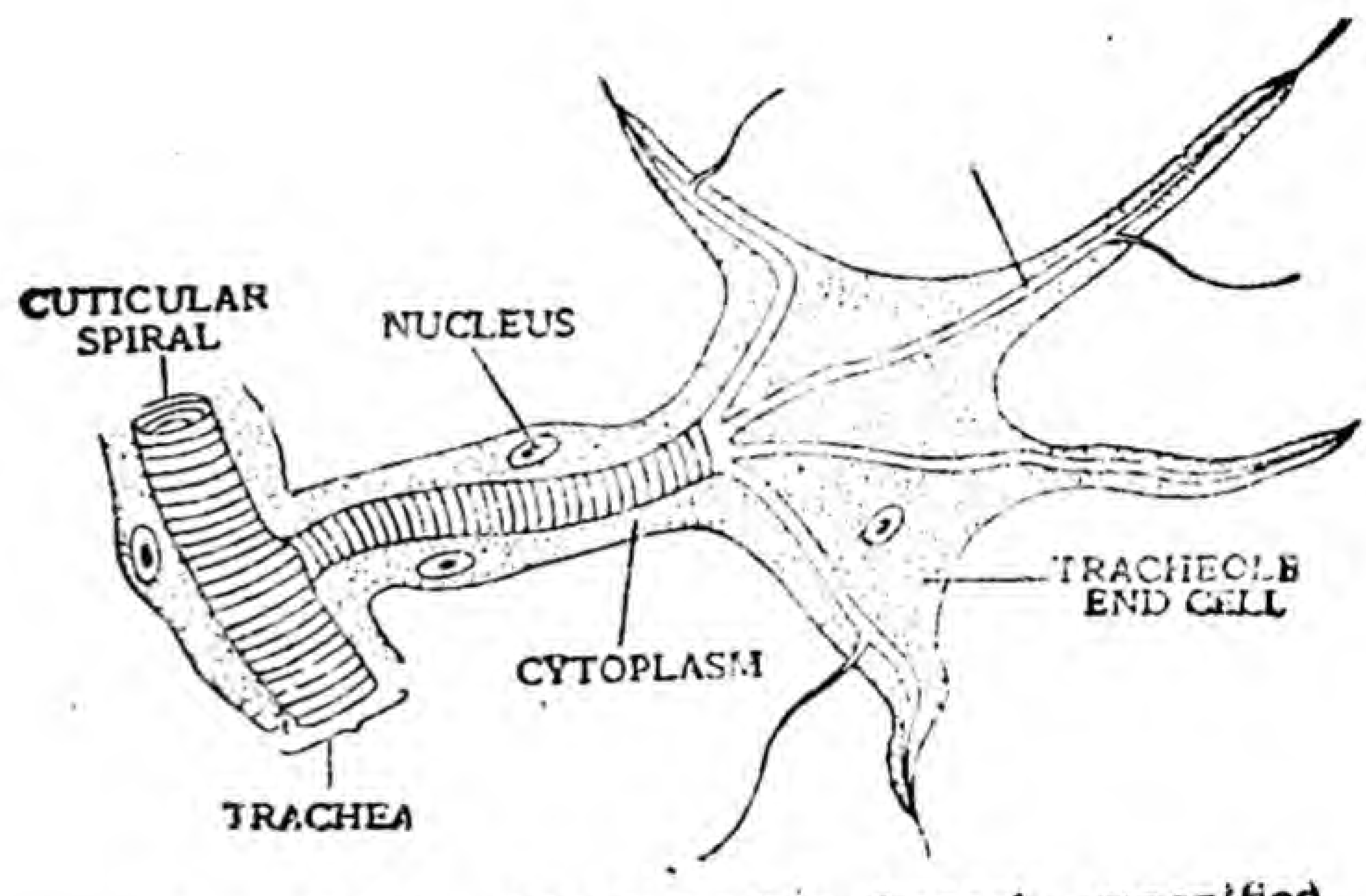


Fig. 12.15. Trachea of cockroach—magnified

from a network of fine tubes, the **tracheoles**. The tracheoles lack chitinous lining (Fig. 12.15). They closely surround the various organs and tissues and penetrate into the living cells. The air can, thus, directly reach all parts of the body. During slow respiratory activities, the tracheoles are partly filled with the tissue fluid which is withdrawn during high respiratory activities.

Mechanism of Respiration. When the cockroach is at rest, its oxygen requirement is less and is met without any special effort on its part. In

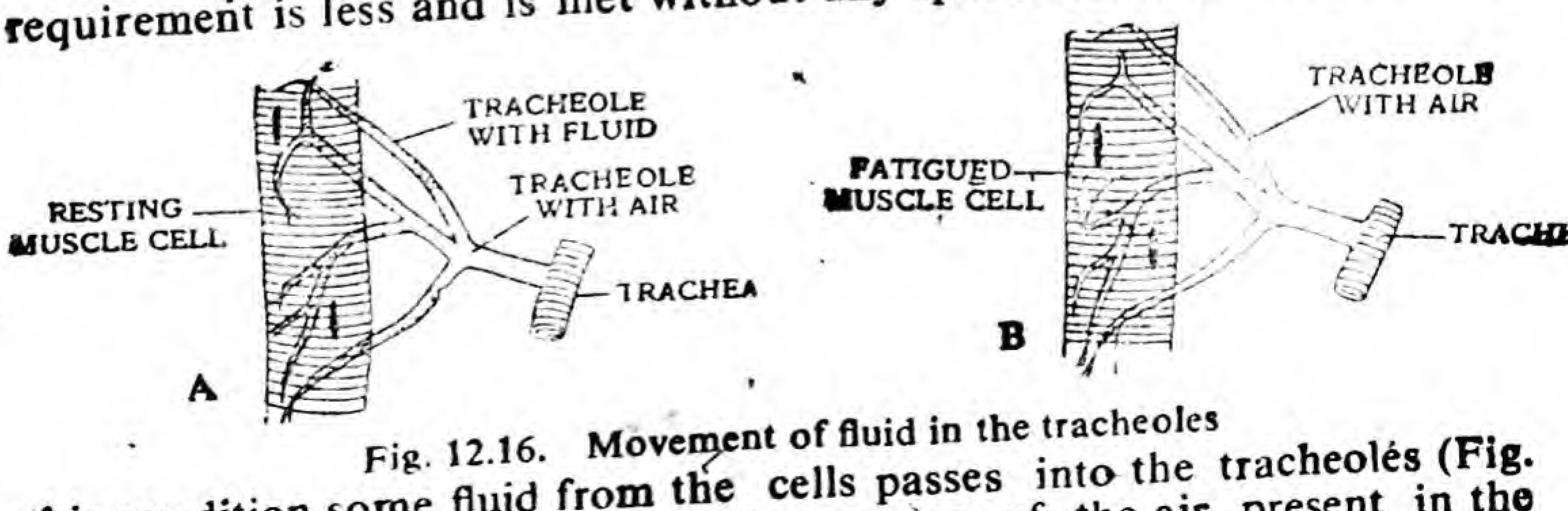


Fig. 12.16. Movement of fluid in the tracheoles

this condition some fluid from the cells passes into the tracheolés (Fig. 12.16 A). This fluid dissolves the oxygen of the air present in the

tracheoles. From the fluid, oxygen diffuses into the cell. Here the oxygen is consumed in the oxidative processes of the cell. With the result, an oxygen gradient is set up between the cells and the tracheoles. The tracheoles in turn draw oxygen from outside through the stigmata.

When the cockroach is running, its oxygen requirement increases and special respiratory movements of the abdomen start. These movements consist of alternate expansion and contraction of the abdomen and are caused by the tergosternal muscles. This brings about inspiration and expiration of air respectively through the stigmata. The first thoracic and the first abdominal stigmata remain open all the time whereas the remaining stigmata open during inspiration and close during expiration. During active respiration, fluid from the tracheoles is drawn back into the cells due to increase in the osmotic pressure of the cells. This enables the air to go deep into the tracheoles and reach the cells directly, thereby increasing the efficiency of respiration (Fig. 12.16 B).

The oxygen absorbed by the cells oxidises the food to release energy which the cockroach uses in its activities. The oxidation also produces water and carbon dioxide. Carbon dioxide diffuses into the surrounding blood from where it is got rid of by diffusion through the cuticle which is permeable to it. Some carbon dioxide is eliminated through the tracheae during expiration. Water is retained in the cells as cockroach cannot drink it.

It is a noteworthy point that the blood does not take any part in the tracheal respiration. This is because the air can directly reach all the tissues of the body through tracheoles.

Circulatory System

The circulatory system is meant for the transport of materials from one part to another in the body. In the cockroach, like other insects, this system is of the '**open**' type as the blood does not circulate in closed vessels but fills the body-cavity which is consequently called the **haemocoel**. There are three main parts in the circulatory system of this animal : **haemocoel**, **heart** and **blood**.

I. Haemocoel. The haemocoel lacks the epithelium of a true coelom. It is divided into three compartments (Figs. 12.12 and 12.20) by two, muscular horizontal membranes : the **dorsal diaphragm** or **pericardial septum** attached laterally to the terga and the **ventral diaphragm** attached laterally to the sterna. Both the diaphragms are perforated by small apertures. The pericardial septum is slightly bulged upwards. There are a series of paired triangular muscles, the **alary muscles**, attached to the pericardial septum by their broad sides and to the terga by their pointed ends or vertices. The bases of the two alary muscles of each pair meet in the median line. The three components of the haemocoel are known as the **pericardial haemocoel** or the **dorsal sinus**, the **perivisceral haemocoel** or the **middle sinus** and the **sternal haemocoel** or the **ventral sinus**. The middle sinus is very large as it contains most of the viscera. The dorsal and ventral sinuses are small as they only have the heart and the nerve-cord respectively.

2. Heart. The heart (Figs. 12.12, 12.17 and 12.18) lies [in the pericardial haemocoel or dorsal sinus. It is a long, muscular, pulsatile tube extending along the mid-dorsalline just beneath the terga of the thorax and abdomen. It is differentiated into thirteen chambers, three in the thorax and ten in the abdomen. Its posterior end is closed while the anterior end is continued forward as the **anterior aorta.** At the anterior end of each chamber there is a pair of valves which only allow the forward flow of blood. At the posterior side of each chamber, except the last, there is a pair of small holes, the **ostia,** one on either side. The ostia are guarded by valves which allow the blood to pass only into the heart from the dorsal sinus.

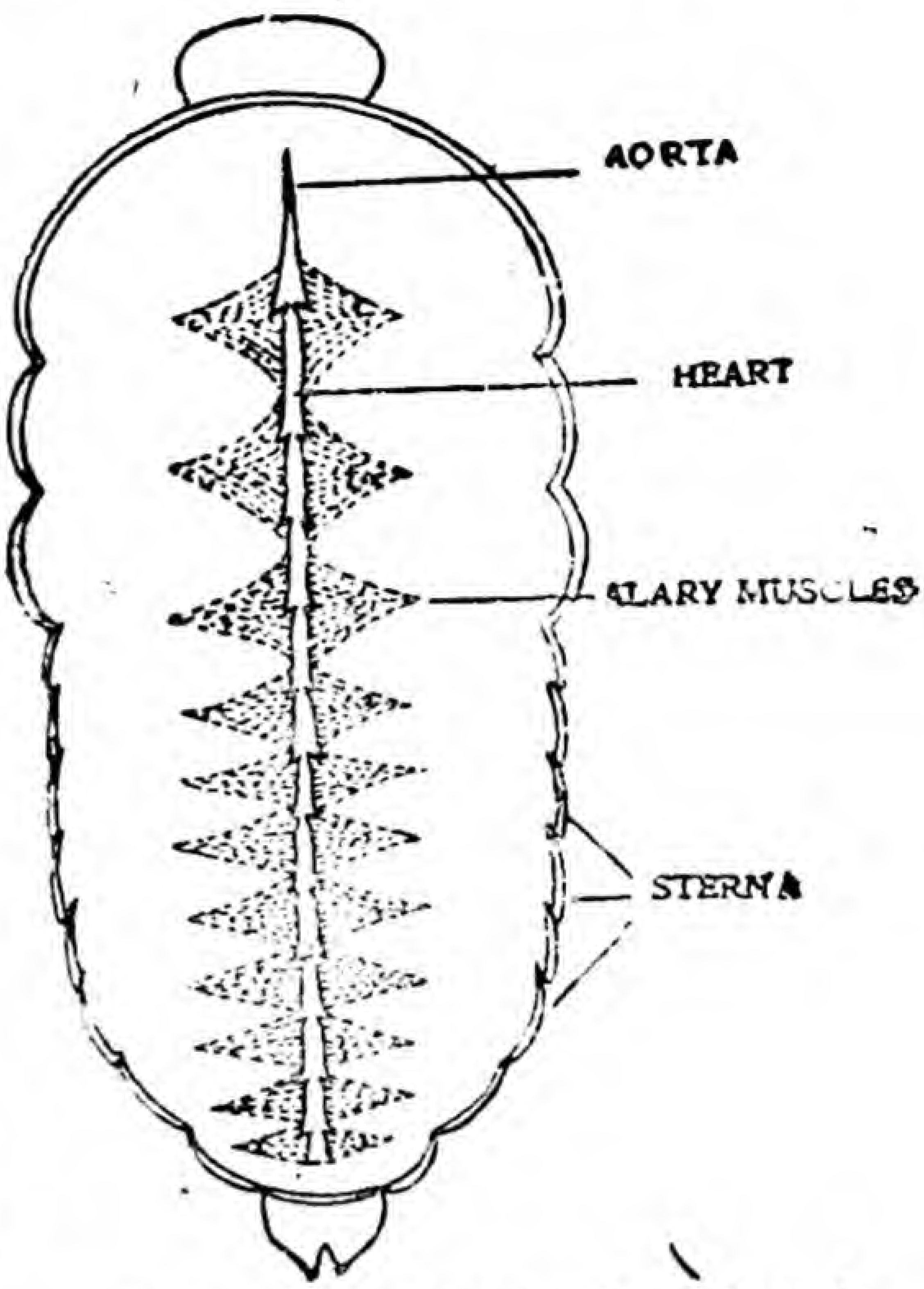


Fig. 12.17. Heart of cockroach (After Grove and Newell)

3. Blood. The blood is colourless and is called **haemolymph.** It consists of a fluid **plasma** containing free blood corpuscles or **haemocytes,** which are of two types : **proleucocytes** and **phagocytes.** The former are small in size but have very large nucleus that almost fills the cell. They divide actively by mitosis. The phagocytes are large and can attack foreign particles like bacteria. There is no respiratory pigment in it as it plays no role in respiration. It performs four important functions. It absorbs food from the alimentary canal and distributes it to the rest of the body. It brings nitrogenous wastes from all parts of the body to the excretory organs for elimination. It carries the defensive phagocytes to the places of infection where they eat up the foreign germs and disintegrating tissues. It transports secretions of the ductless glands to the required organs.

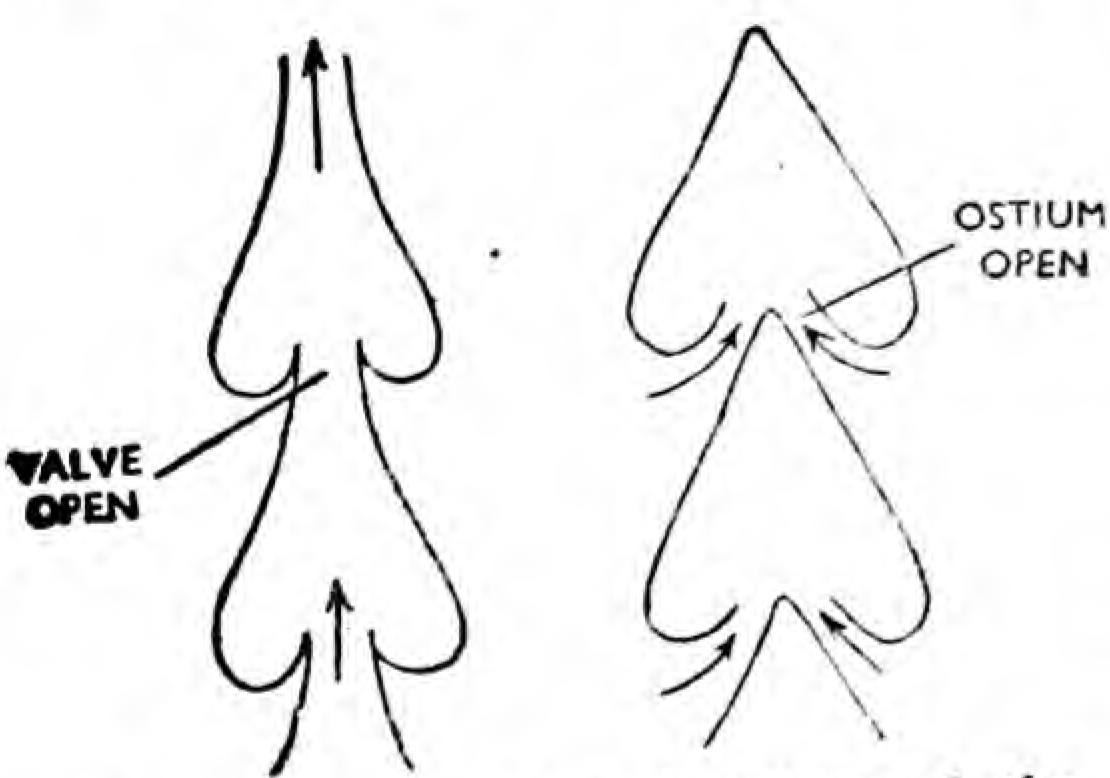


Fig. 12.18. A few chambers of the heart of cockroach showing the ostia

Circulation of Blood. The blood flows forward in the heart by rhythmic contractions of its wall. At the anterior end of the heart,

it enters the anterior aorta which pours it into the head sinuses. From the head sinuses the blood flows into the perivisceral and sternal haemocoels. Now the alary muscles contract. The pericardial septum becomes flat. This increases the capacity of the pericardial haemocoel. The blood, therefore, flows from the perivisceral haemocoel into the pericardial hoemocoel through the perforations of the pericardial septum. On relaxation of the alary muscles, the pericardial septum bulges upwards. This presses the blood which enters the heart through the ostia from the pericardial haemocoel.

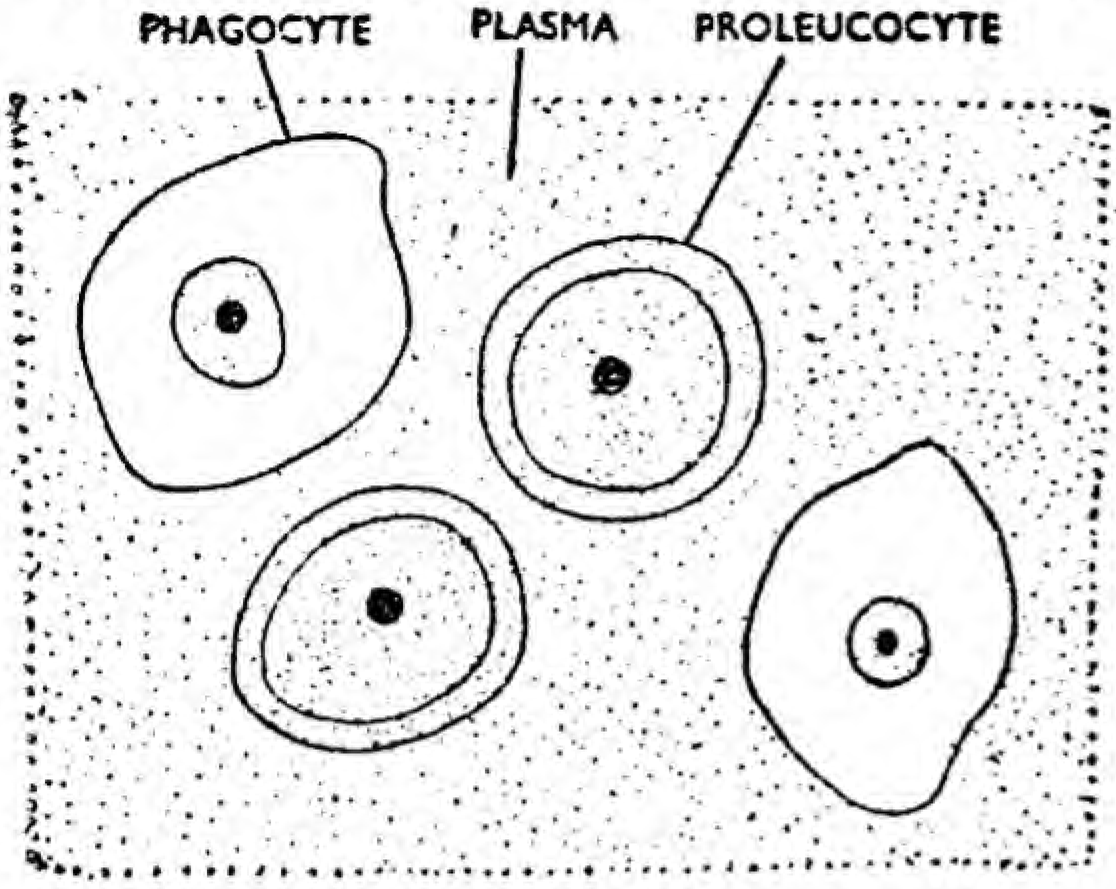


Fig. 12.19. Haemolymph (Blood) of cockroach

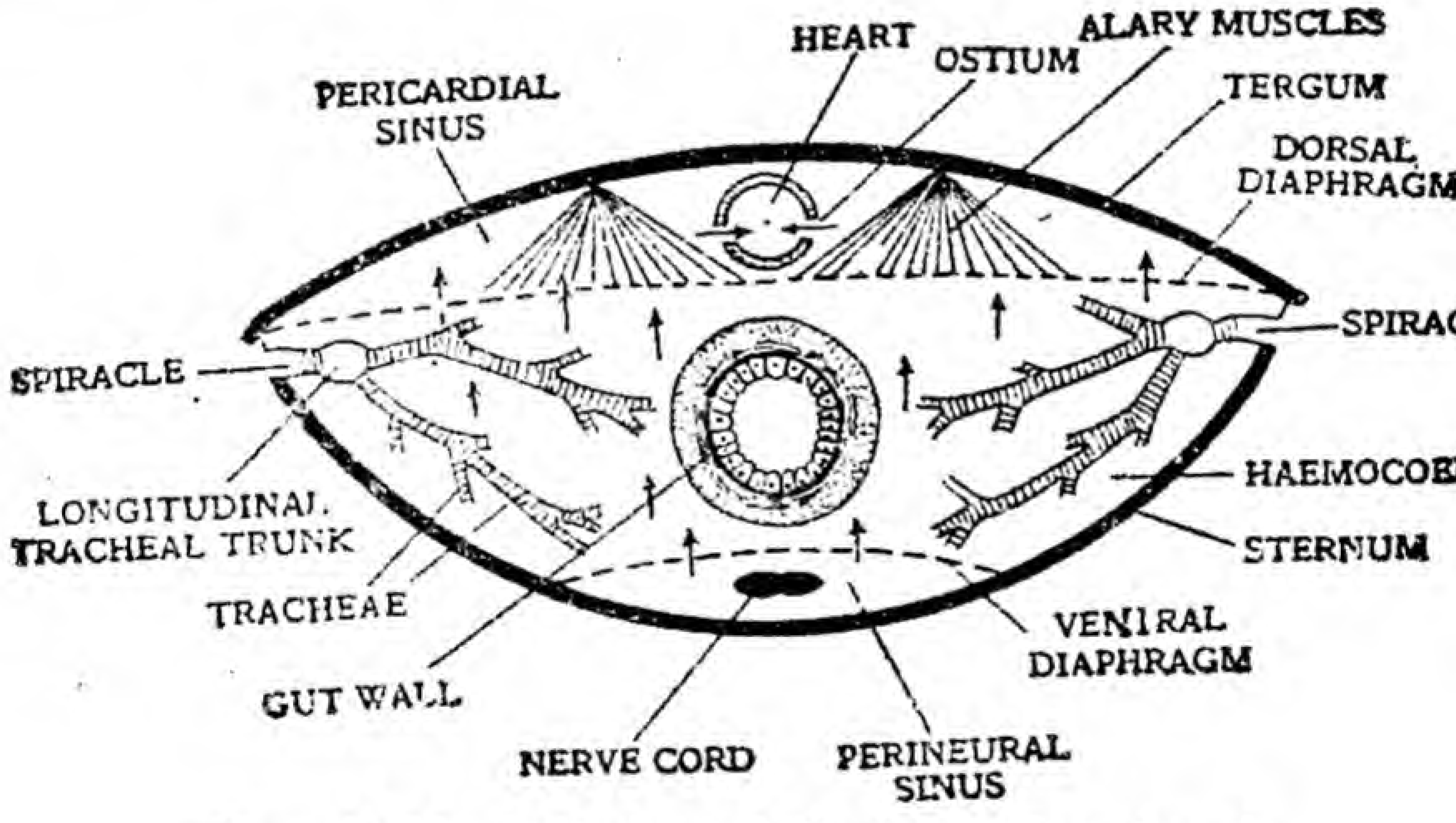


Fig. 12.20. T.S. through the body of cockroach

Excretory System

The excretory system is meant for the elimination of nitrogenous waste materials from the body. This system is very simple in cockroach. It consists of a large number of very fine, yellowish, thread-like processes, the **Malpighian tubules**, which open into the anterior end of the ileum (Fig. 12.12). They are arranged in six groups, each group having about fifteen tubules. The Malpighian tubules arise as outgrowths from the ileum and are, thus, ectodermal in nature. They float freely in the haemolymph of the haemocoel but do not open into it, being blind at the free ends. Each tubule is formed of a single layer of glandular cells surrounded by a basement membrane. The cells have characteristic brush border (Fig. 12.22). The glandular cells of the Malpighian tubules extract water, salts and nitrogenous wastes, chiefly in the form of salts of uric acid, from the haemolymph and pass them

into the lumen of the tubules. From here the extracted materials move in solution, called urine, towards the ileum. The cells of the more proximal part of the tubules absorb water and certain inorganic salts from the urine. This results in the precipitation of uric acid in the lumen of the tubules. By gentle contractions of the tubules, the precipitated mass is carried into the ileum. In the hind-gut, more water is absorbed from the precipitated mass so that almost solid uric acid is finally thrown out with the faeces.

HEAD SINUSES ← AORTA ← HEART

HEART ↑ DORSAL SINUS ↑ MIDDLE AND VENTRAL SINUSES

HEAD SINUSES → MIDDLE AND VENTRAL SINUSES

Fig. 12.21. Plan of blood circulation in cockroach

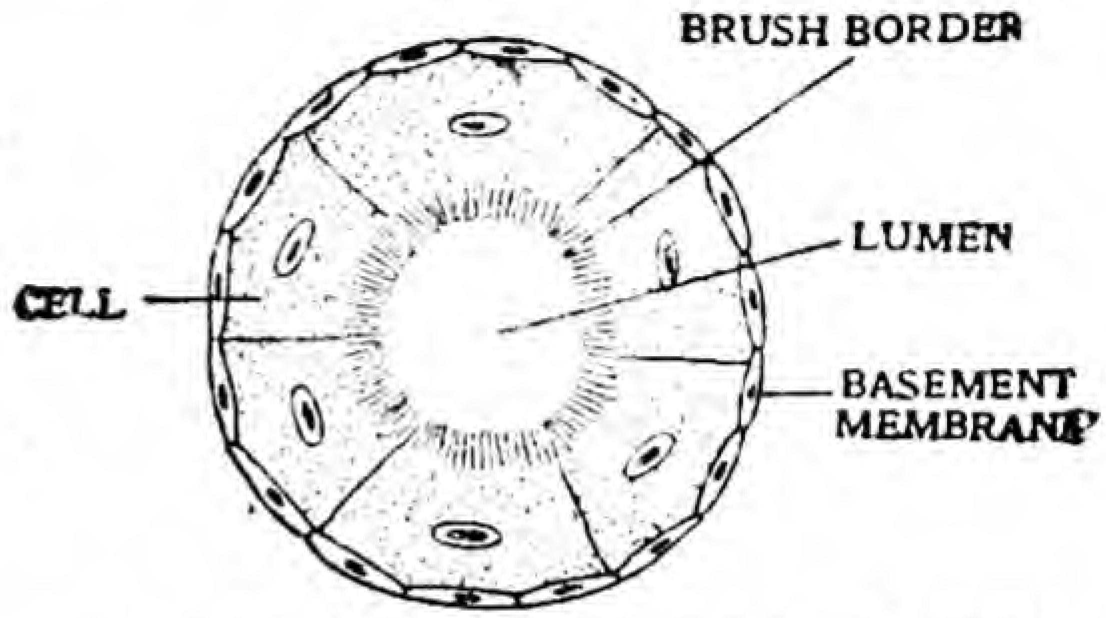


Fig. 12.22. T.S. of a Malpighian tubule

The elimination of nitrogenous waste materials through the alimentary canal is an adaptation for conserving water by reabsorption in the rectum. This is necessary because cockroach cannot drink water.

Some uric acid is stored in special cells of the fat body and remains there throughout the life of the cockroach. This is excretion by storage.

Nervous System

The nervous system controls and co-ordinates the working of all parts of the body.

The nervous system of cockroach is similar to that of earthworm in its general plan. It comprises three main parts : the **central nervous system, peripheral nervous system** and **autonomic nervous system.**

1. Central Nervous System (Fig. 12.23). The central nervous system has four components : **supraoesophageal** or **cerebral ganglion**, **suboesophageal ganglion, circumoesophageal connectives** and **nerve cord**. The supraoesophageal ganglion serves as the brain. It lies in the head above the oesophagus almost between the bases of the antennae. It is a white bilobed mass and is formed by the fusion of three pairs of ganglia. The suboesophageal ganglion is a relatively small white mass. It also lies in the head but beneath the oesophagus. It, too, is formed by the fusion of three pairs of ganglia. The circumoesophageal connectives are short broad bands which encircle the oesophagus connecting the supra- and suboesophageal ganglia. All these three structures together from the **nerve-ring** round the oesophagus in the head capsule. The nerve-cord starts from the suboesophageal ganglion and runs backwards through the thorax and abdomen beneath the alimentary canal. It is solid, double and midventral. It bears nine ganglia, three thoracic and six abdominal. The thoracic ganglia lie in the pro-, meso- and metathorax and are respectively called the

prothoracic ganglion, the **mesothoracic ganglion** and the **metathoracic ganglion**. The abdominal ganglia lie in the first, second, third, fourth, sixth and seventh segments of the abdomen. The throracic ganglia of the nerve-cord are formed by the fusion of a pair of ganglia each except the last abdominal ganglion which is formed by the fusion of a number of ganglia (probably three pairs).

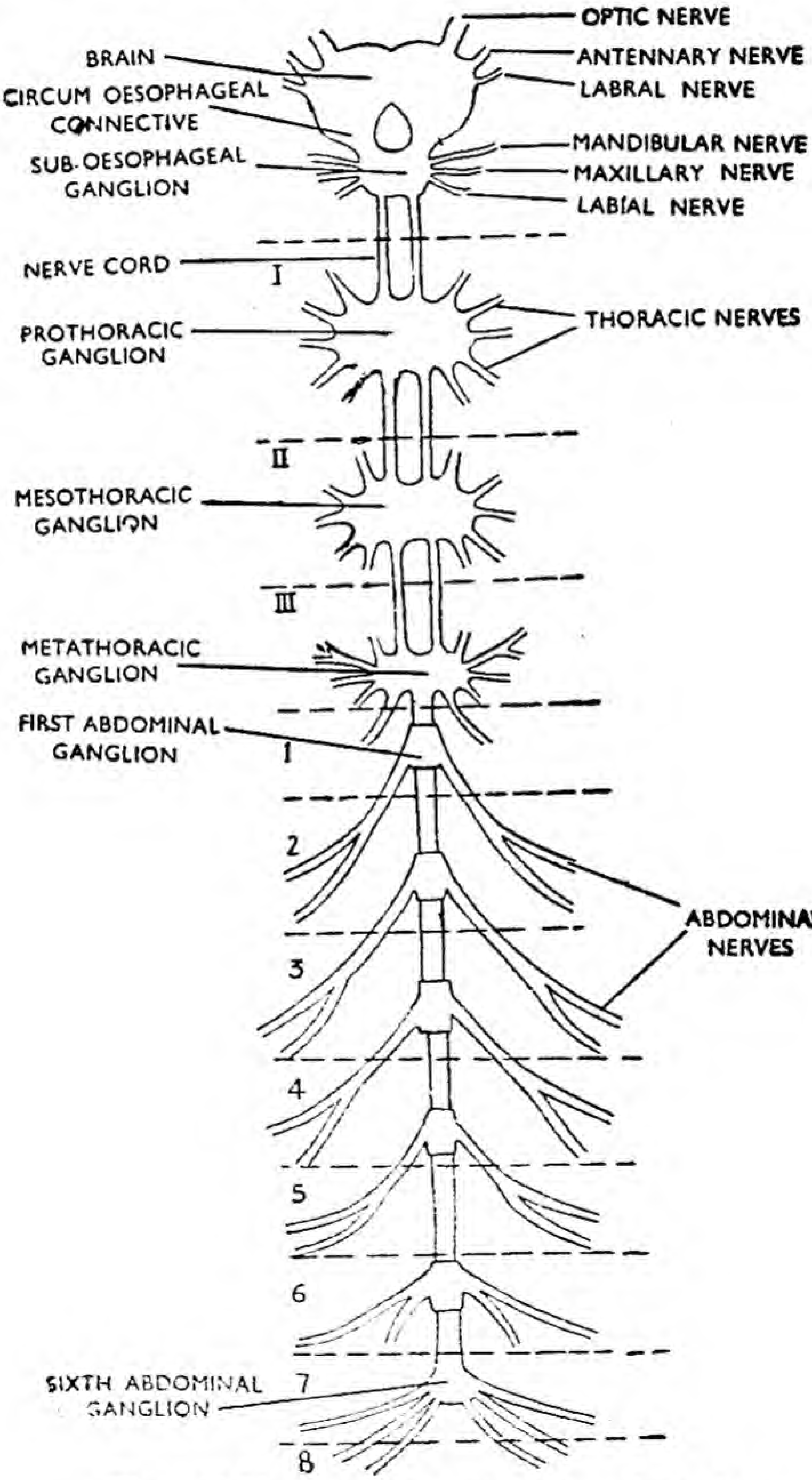


Fig. 12.23. Nervous system of cockroach

2. **Peripheral Nervous System.** The peripheral nervous system (Fig. 12.23) consists of the nerves which arise from the central nervous system and go to the various parts of the body. Three pairs of nerves

arise from the brain. These are called the **optic, antennary** and **labrofrontal nerves**. The first two innervate the compound eyes and antennae respectively. The third soon divides into two : the **labral nerve** which goes to the labrum and the **frontal connective** which runs forwards and towards the median line to join the frontal ganglion of the sympathetic nervous system. The suboesophageal ganglion provides three pairs of nerves : the **mandibular, maxillary,** and **labial** to the mandibles, maxillae and labium. Several pairs of nerves arise from each thoracic ganglion and innervate the parts of their own segment. The metathoracic ganglion, however, sends a pair of nerves to the first abdominal segment. Each of the first five abdominal ganglia give off a pair of nerves, each dividing into two branches. These nerves run backwards and supply the second, third, fourth, fifth and sixth abdominal segments. The sixth abdominal ganglion gives off three pairs of nerves to the seventh, eighth and ninth segments. It also sends a thick nerve to each cercus.

3. Autonomic Nervous System. (Fig. 12.24). The sympathetic or stomatogastric nervous system includes a few ganglia and connectives. There is a **frontal ganglion** situated on the oesophagus just in front of the brain. It is connected with the brain by a branch, called the **frontal connective** of the labro-frontal nerve. From the frontal ganglion, a median nerve, the **frontal nerve**, passes backwards and bears the **occipital ganglion** behind the brain. From the occipital ganglion arise three nerves, two lateral and one median. The lateral nerves meet the corpora cardiaca (see endocrine glands). The median nerve runs backwards over the oesophagus and joins the **ingluvial ganglion** situated on the crop. From the ingluvial ganglion, a pair of nerves proceed backwards over the alimentary canal.

Sense Organs

The sense organs are meant for perceiving the external stimuli. The cockroach possesses organs for all the five popular senses, namely, touch, taste, smell, hearing and sight. The receptor-organs for touch, taste, smell and hearing are quite simple and are called **sensillae**. A sensilla (Fig. 12.25) consists of a bipolar **sensory cell** associated with a fine pointed **seta** secreted by a large epidermal cell, the **trichogen cell**. The seta projects from a **socket** to the walls of which it is movably articulated by a thin ring-like **cuticular membrane.** One end of the sensory cell is connected with the cuticular membrane while the other is continued as a fine nerve fibre that passes into the central nervous system. Movement of the seta caused by contact, wind, etc. stimulates the sensory cell which sets up and transmits a suitable senory impulse to the central nervous system. The **tactile** (touch) **sensillae** are found all over the body but are specially plentiful on the antennae, tibiae of legs and anal cerci The **gustatory** (taste) **sensillae** are present on the tips of the maxillary and labial palps and on the epipharynx. The **olfactory** (smell) **sensillae** lie on the antennae and the palps. The sensillae on the antennae perceive smell from a distance while those on the palps perceive it only from close quarters. The **auditory**

(hearing) **sensillae** are located on the anal cerci. The antennae, perhaps, also bear sensillae for humidity and temperature.

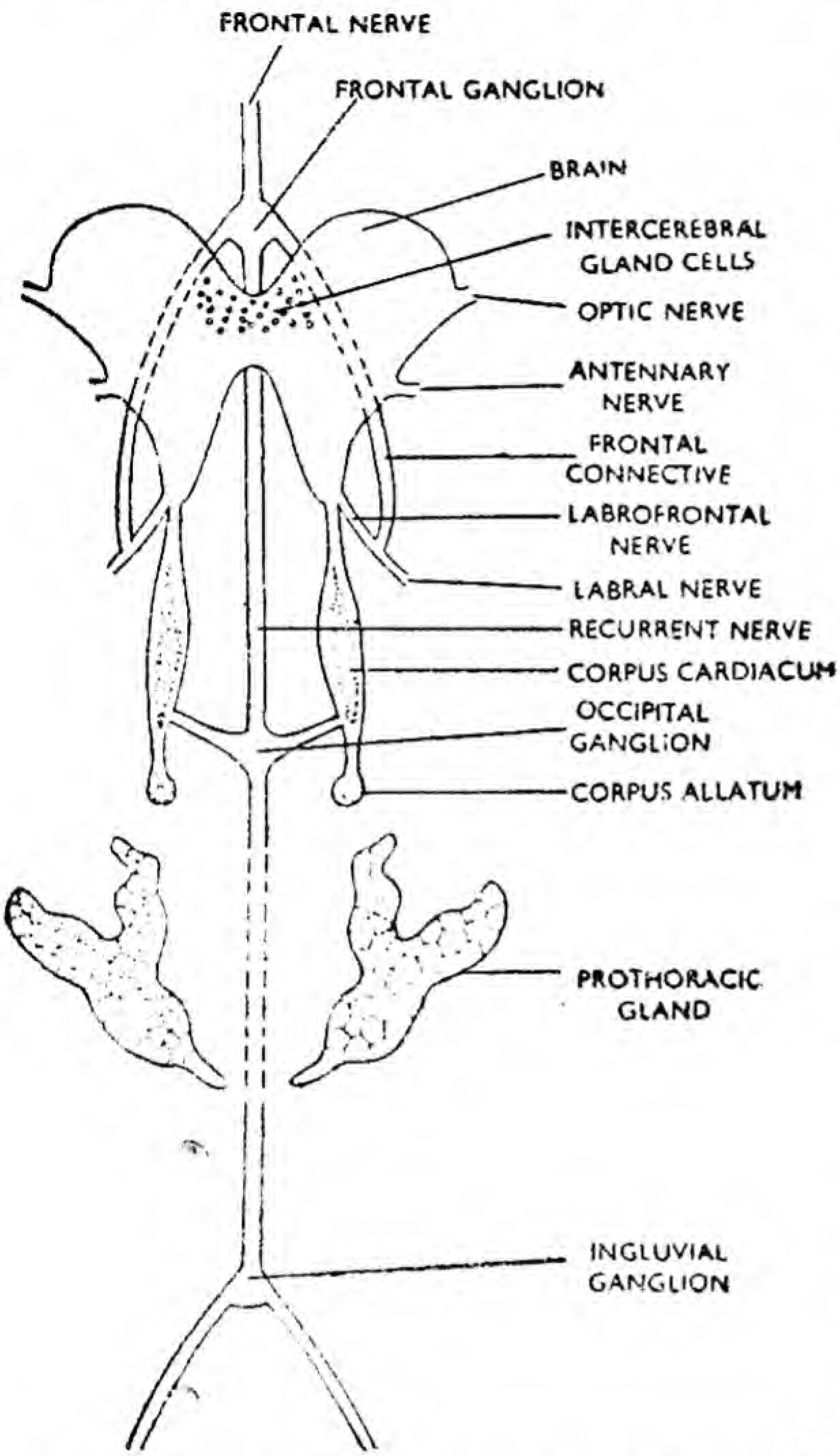


Fig. 12.24. Sympthetic nervous system and endocrine glands of cockroach

The compound eyes are the organs of sight. They are large, black, kidney-shaped structures situated dorso-laterally on the head. They are covered with transparent cuticle forming the **cornea.** Each eye is composed of about 2,000 distinct units known as the **ommatidia.** The ommatidia are radially arranged so that the outer surface of the eye is much broader than the inner one (Fig. 12.27). All the ommatidia have a similar structure. Each ommatidium is represented on the surface of the eye by a hexagonal part of the cornea. This is biconvex in form and is called the **corneal lens** or **facet**. (Fig. 12.26). Just inside the corneal lens are two clear epidermal (hypodermal) cells which secrete the lens. These are called the **corneagen cells.** Behind the corneagen cells lies a transparent conical structure, the **crystalline cone,** with its base directed outwards. The crystalline cone is secreted by **cone cells** which surround it on all sides. All the above structures collectively form the focussing or **dioptric part** of the ommatidium. Just behind the cone is a long, narrow, cylindrical body, the **rhabdome.** It is secreted and surrounded by elongated cells, the **retinulae.** The inner end of each retinula is continued into a nerve-fibre which joins the optic nerve. The rhabdome and the retinulae form the receptive part of the ommatidium. The ommatidium is bounded internally by **a basement membrane.** This membrane is pierced by the nerve-fibres of the retinulae.

Each ommatidium is ensheathed by densely pigmented cells which optically separate it from the adjacent ommatidia. There are two sets of these pigmented cells : the **iris pigment cells** round the dioptric part **and retinal pigment cells** round the receptive part.

During bright light the dioptric parts of the ommatidia are completely enveloped by the pigment cells. The ommatidia are, thus, optically

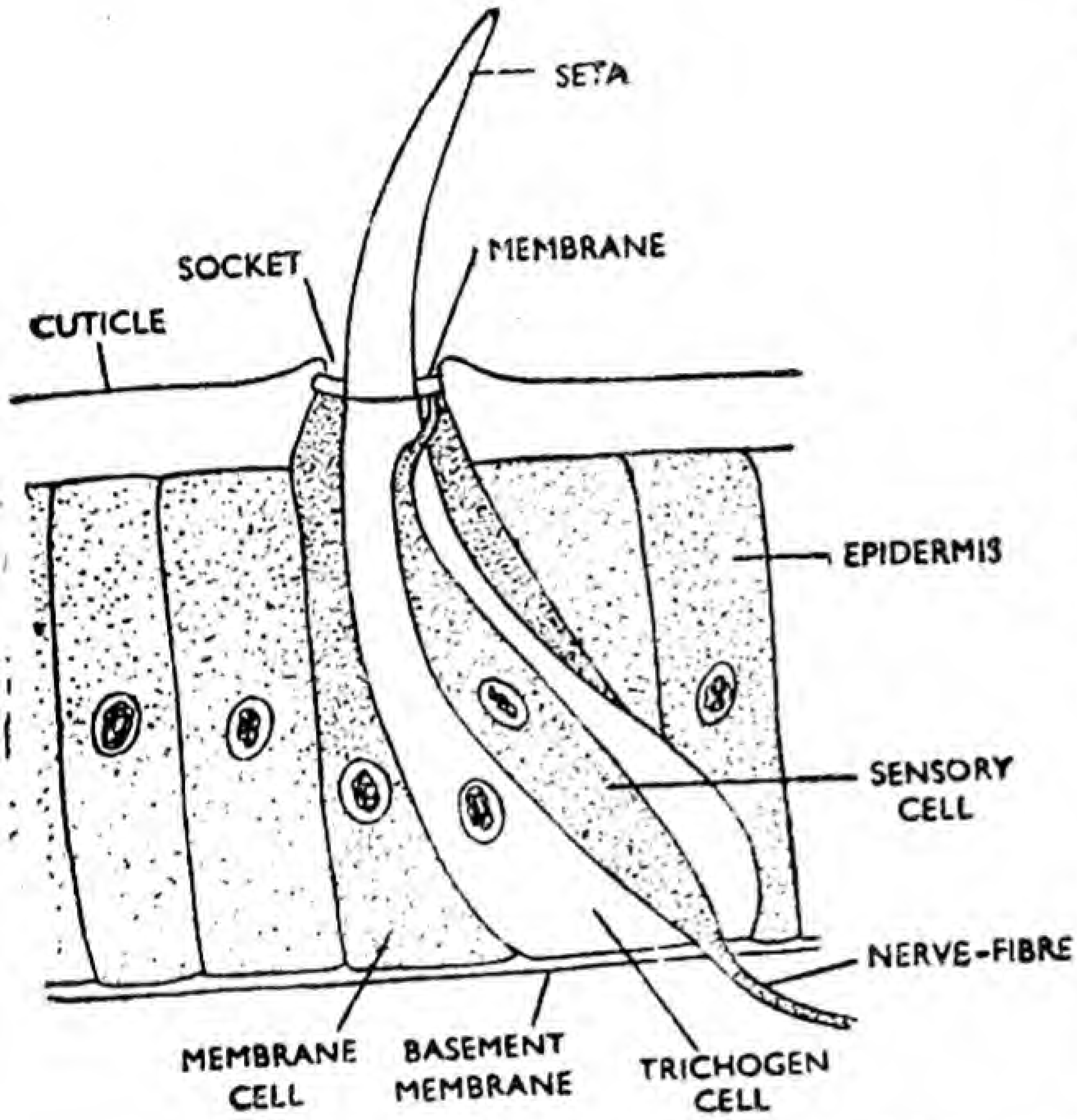


Fig. 12.25. A sensilla of cockroach

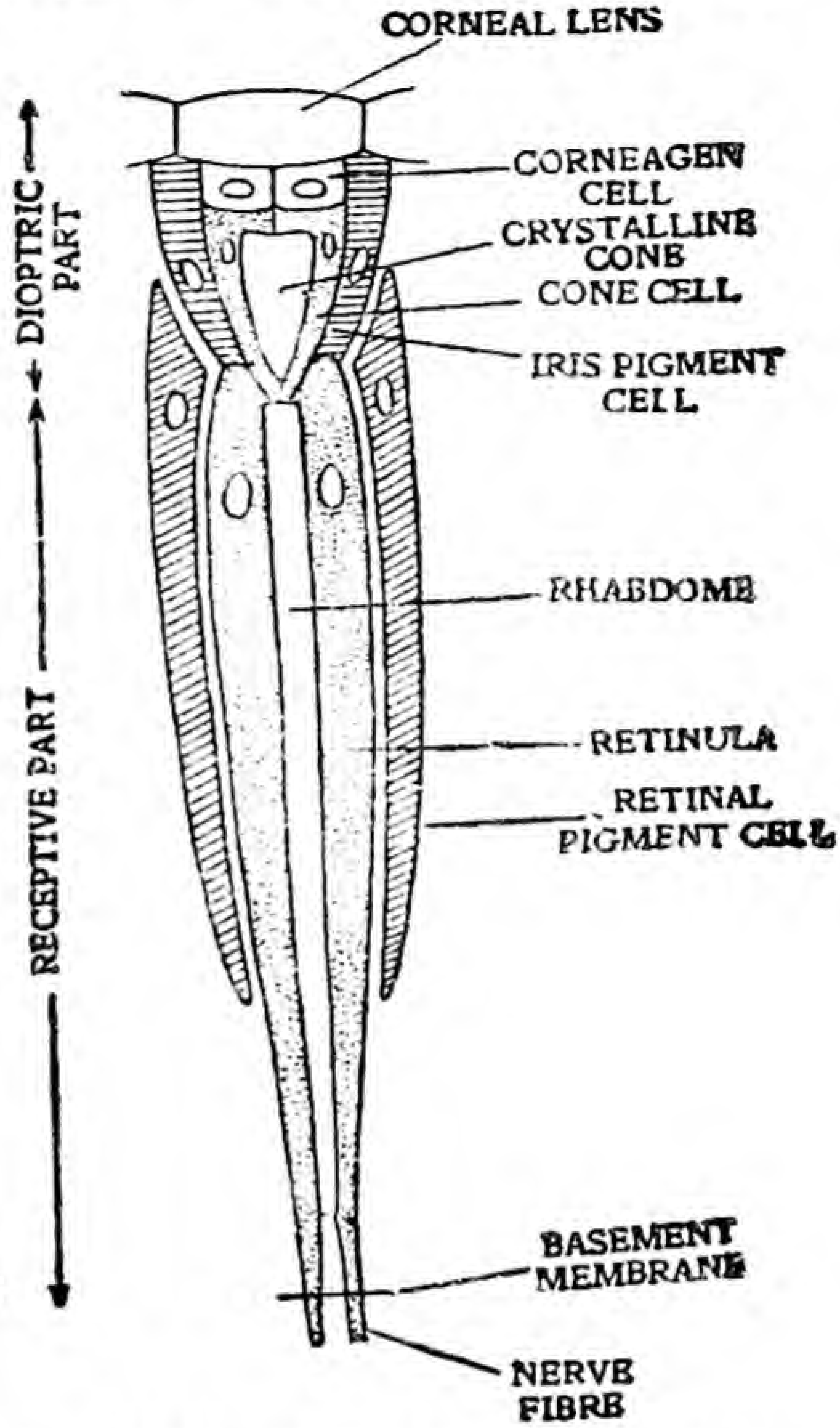


Fig. 12.26. L.S. of an ommatidium

separate from one another. With the result, only those rays of light, which enter an ommatidium running parallel to its long axis, come to a point on its rhabdome. The rays, which enter obliquely, fall on the pigment cells and are absorbed. Thus, the image seen by the eye is formed by several points of light lying side by side, one in each ommatidium. Such an image is called the **apposition** or **mosaic image** and the eye is said to have a **mosaic vision.**

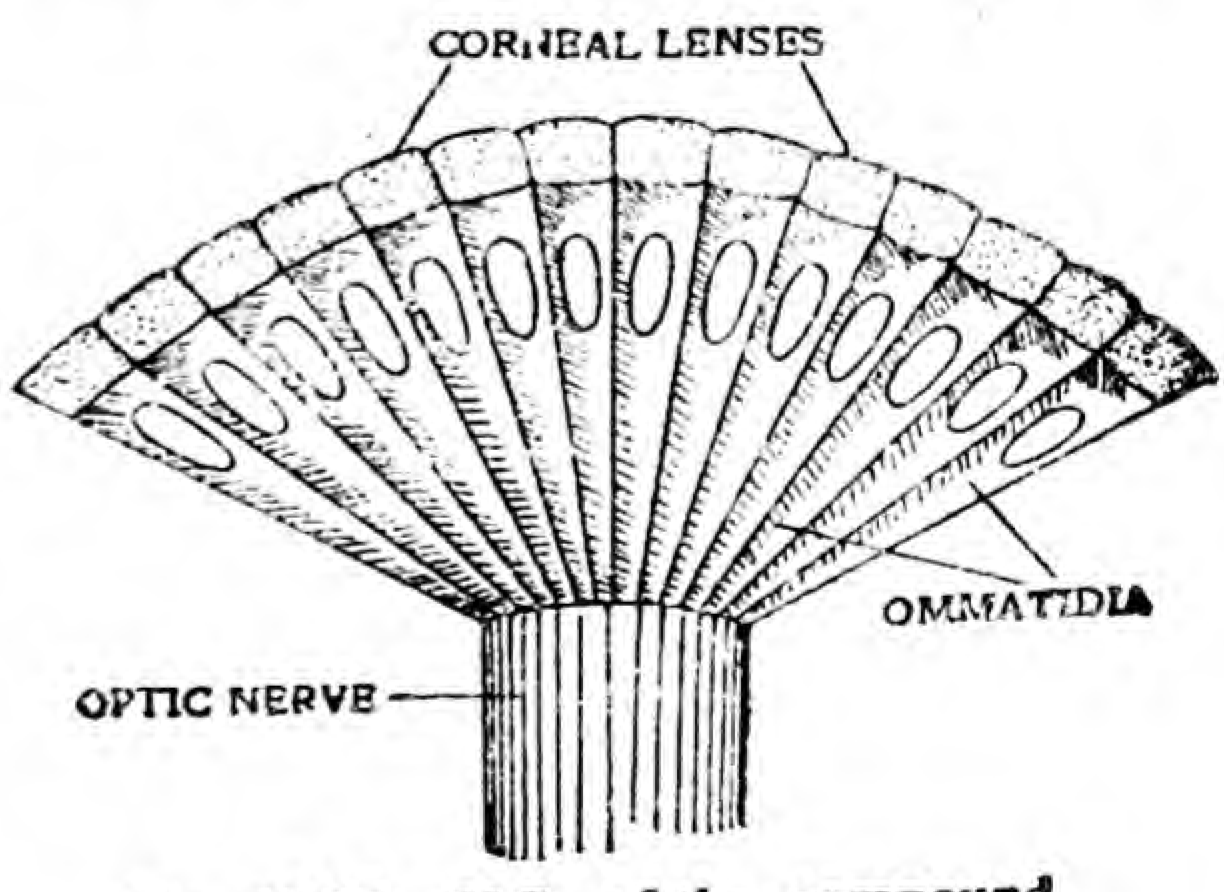


Fig. 12.27. V.S. of the compound eye of cockroach

During dimlight the iris pigment cells and the retinal pigment cells retract apart and expose the dioptric parts of the ommatidia. With the result, the rays

of light entering several adjacent corneal lenses can reach the same rhabdome. Thus, the image seen by the eye is formed by overlapping points of light. Such an image is called the **superposition image.** This image is not as sharp as the apposition image. But objects give better impressions with superposition image in dim light as no light rays are **absorbed.**

In cockroach the pigment cells are not retractile and it sees only by apposition images.

Endocrine System (Fig. 12.24)

The endocrine system regulates certain phenomena by chemical secretions directly released into the blood. These secretions are known as the **hormones** and the glands producing them as the **ductless** or **endocrine glands.** The endocrine glands of insects include the **intercerebral glands, corpora allata, corpora cardiaca** and **prothoracic glands.**

1. **Intercerebral Glands.** The intercerebral glands are secretory cells within the brain between the two cerebral ganglia. They secrete a hormone, the "brain hormone", which activates the prothoracic glands situated in the prothorax to release their hormone called **ecdyson.** The latter controls the growth and moulting of the nymphs. The prothoracic glands degenerate after metamorphosis.

2. **Corpora Cardiaca.** The corpora cardiaca are a pair of slightly elongated bodies situated on the sides of the oesophagus just behind the brain. They secrete a growth hormone.

3. **Corpora Allata.** The corpora allata are a pair of small rounded bodies lying behind the corpora cardiaca. They secrete a **juvenile hormone** in the nymphal stages. This hormone causes retention of the nymphal characters and checks the appearance of adult characters. In other words, it keeps the insect young, hence its name. In the last nymphal form, the corpora allata become inactive, thereby resulting in the absence of the juvenile hormone. The absence of this hormone permits the appearance of adult features. In the adult, the corpora allata, again, become active and secrete a **gonadotropic hormone**, which regulates egg formation and development and functioning of the accessory sex glands. In the virgin female adult cockroach, the corpora allata also control the production of volatile sex attractants. which are picked up by chemoreceptors of the male's antennae.

It is interesting to note that the endocrine glands are innervated by the sympathetic nervous system as in the vertebrates.

Reproductive System

The reproductive system is meant for the propagation of the species. The cockroach is **unisexual** with a distinct **sexual dimorphism**. The females can be distinguished from the males by the short and broad abdomen, presence of brood pouch, and absence of anal styles.

1. **Male Reproductive System** (Fig. 12.28). The reproductive organs of the male cockroach are a pair of **testes.** They are elongated lobed structures situat d dorso-laterally in the fourth and fifth abdominal

segments. They are embedded in the fat body. The testes are full of

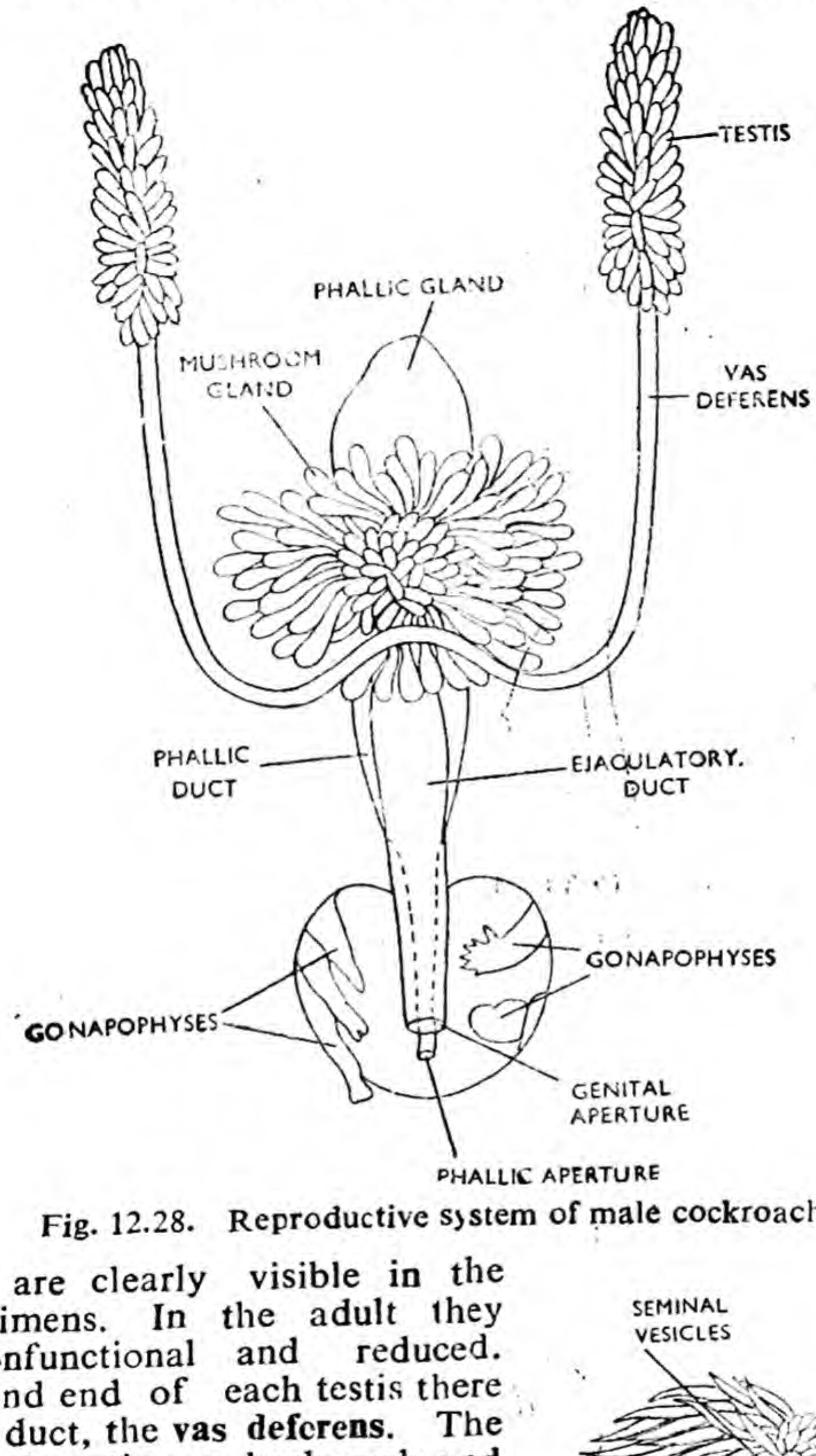


Fig. 12.28. Reproductive system of male cockroach

sperms and are clearly visible in the young specimens. In the adult they become nonfunctional and reduced. From the hind end of each testis there starts a fine duct, the **vas deferens.** The two vasa deferentia run backwards and inwards to open into a wide median duct, the **ductus ejaculatorius,** in the seventh segment. The opening of the vasa deferentia into ductus ejaculatorius is masked by a large structure called the **mushroom or utricular gland.** This gland consists of a number of blidd finger-like diverticula of different sizes opening into the anterior end of the ductus ejaculatorius. The diverticula are

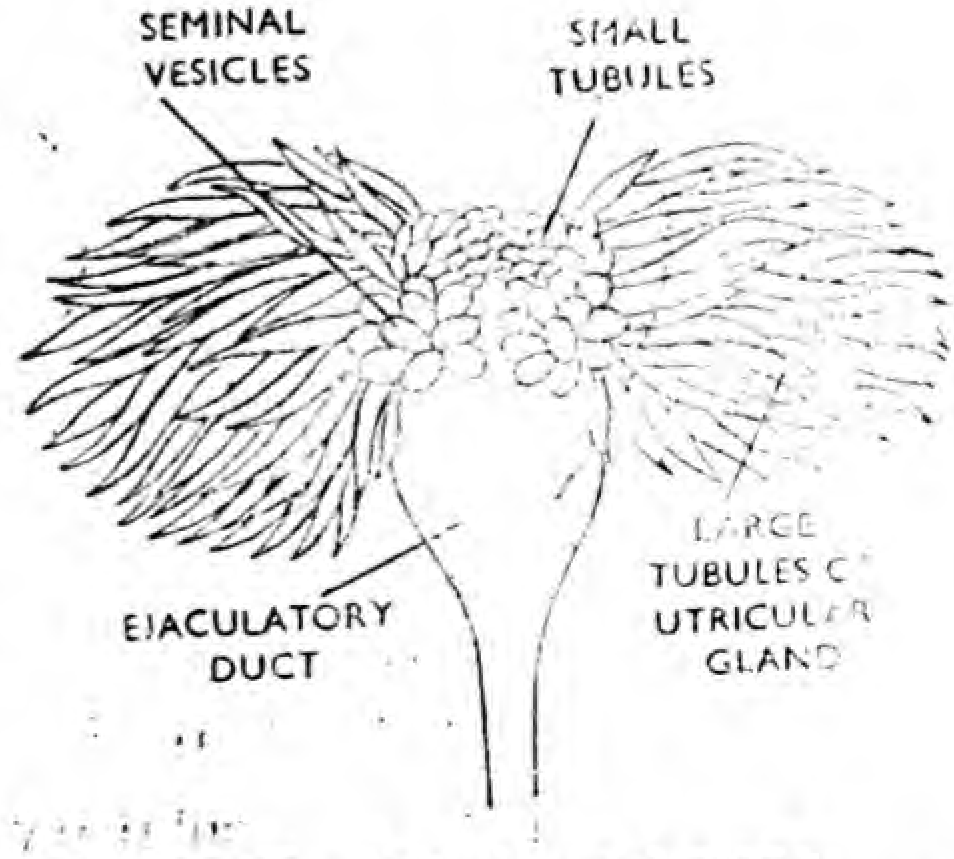


Fig. 12.29. Mushroom gland

of three types : peripheral **long tubules**, antero-median **short tubules** and postero-median short but bulbous tubules known as the **seminal vesicles.** The ductus ejaculatorius runs backwards and opens out at the male genital aperture situated below the anus. A large, white, elongated, sac-like **conglobate or phallic gland** lies beneath the ductus ejaculatorius. It tapers posteriorly to form a **phallic duct** that opens out near the male genital aperture.

The male genital aperture is surrounded by three irregular chitinous process, the **gonapophyses** or **phallomeres** (Fig. 12.30). These aid in copulation and, thus, act as the **external genitalia.**

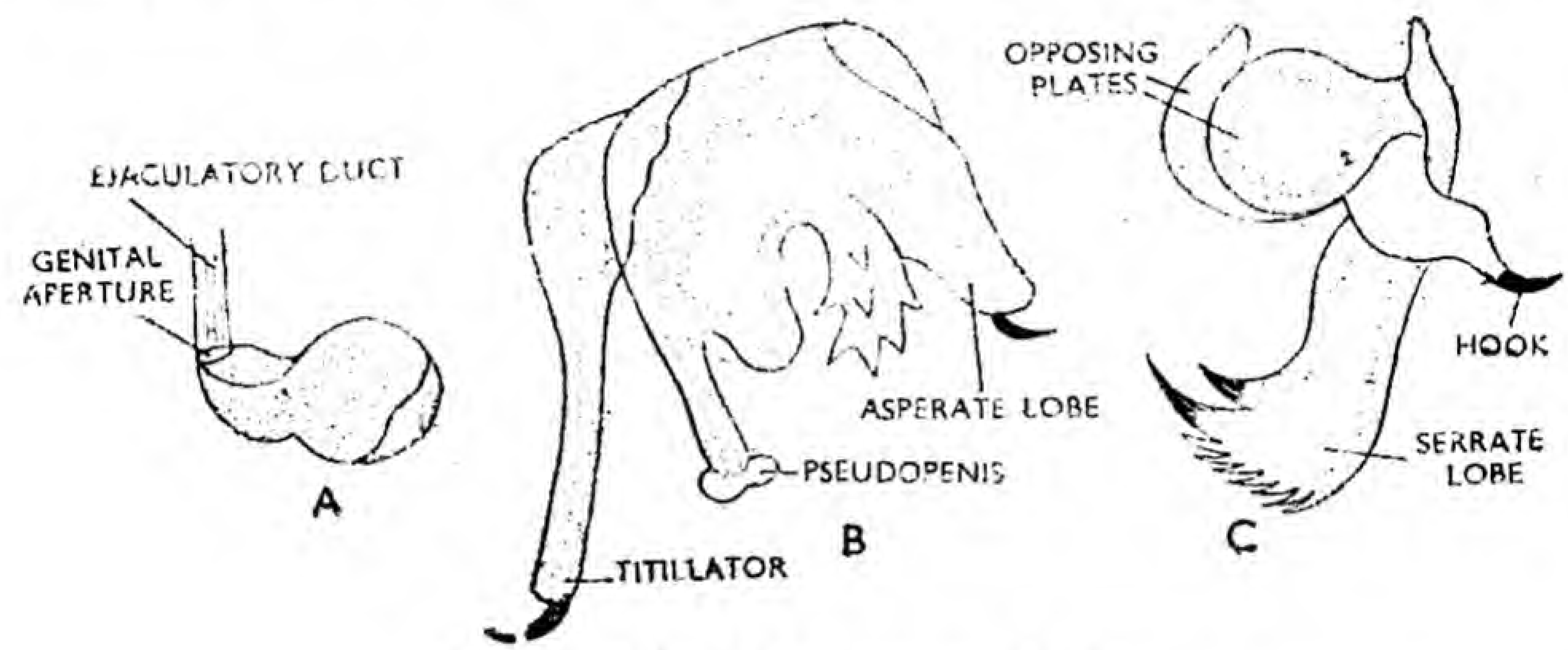


Fig. 12.30. Male gonapophyses.

The testes produce spermatozoa, which are brought by the vasa, deferentia into the seminal vesicles for storage. The spermatozoa in each seminal vesicle stick together to form a single bundle. This bundle, along with some secretion of the short tubules of the utricular gland, gets enclosed in a wall. The structure, thus formed, is known as the **spermatophore.** The wall of the spermatophore is one-layered to begin with, but later becomes three-layered (Fig. 12.31). The inner layer is formed of the secretion of the long tubules of the utricular gland. During copulation, the spermatophore with a single-layered wall

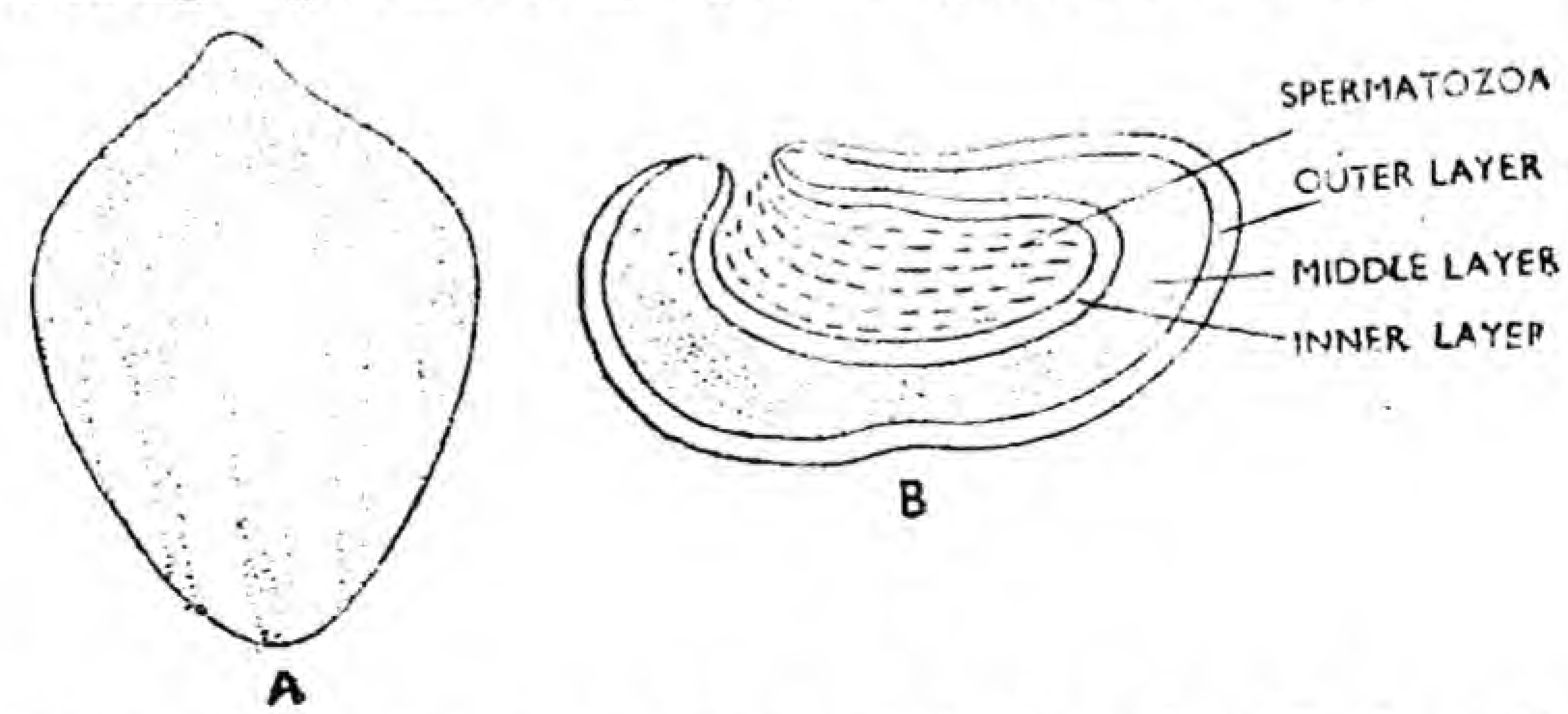


Fig. 12.31. Spermatophore. A—Surface view, B—in section.

travels down the ejaculatory duct, where the middle layer is added around it from the secretion of the ejaculatory duct itself. Finally,

the spermatophore is attached to the spermathecal papilla of the female, where the secretion of the phallic gland is poured over it to form the outer layer. A fully formed spermatophore is a pear-shaped capsule, about 1·3 mm. in diameter.

2. Female Reproductive System (Fig. 12.32). The reproductive organs of the female cockroach are a pair of **ovaries.** They lie

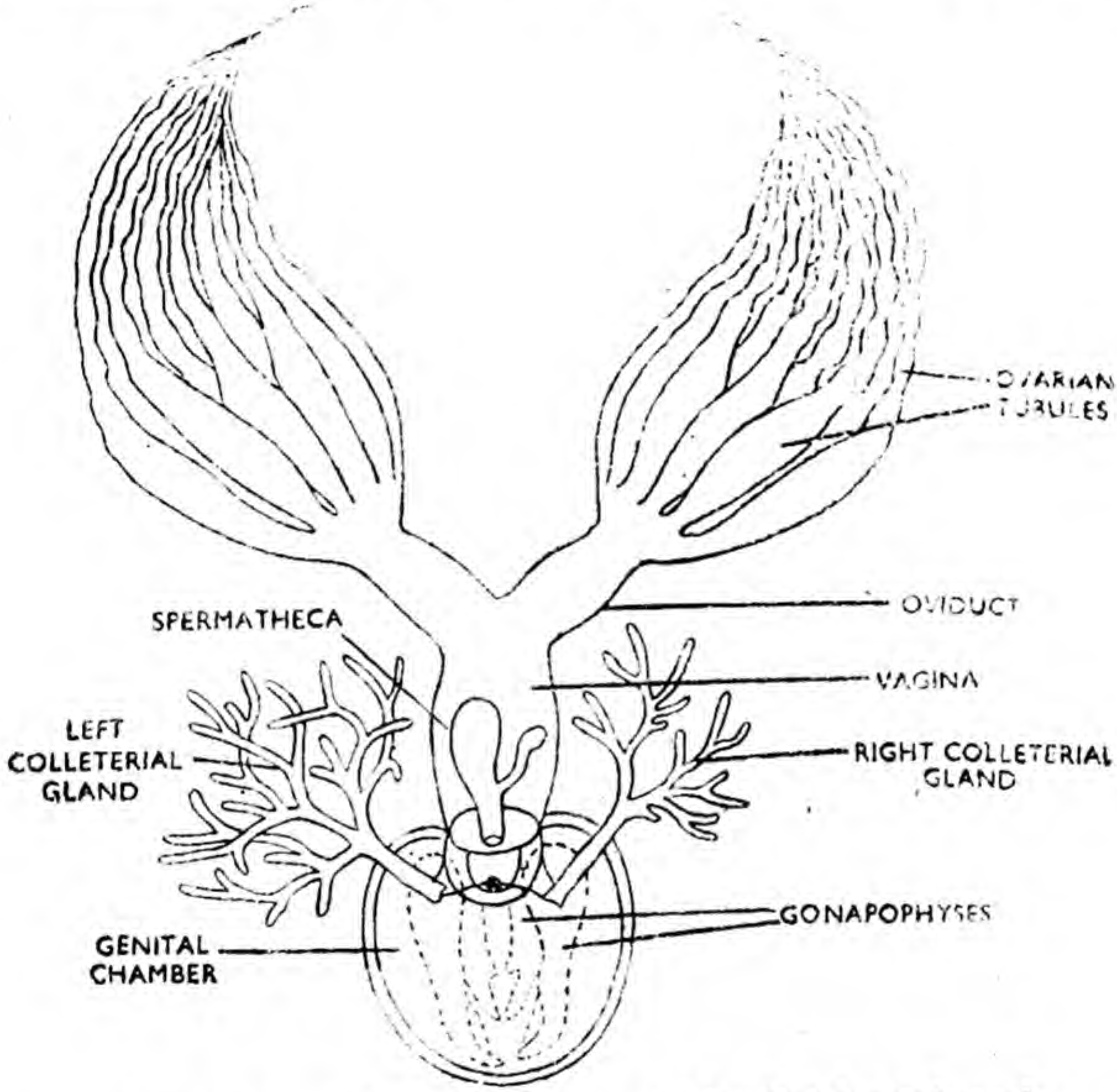


Fig. 12.32. Reproductive system of a female cockroach

beneath the fourth, fifth and sixth abdominal terga, one on each side. They are yellowish in colour and are embedded in the fat body. Each ovary consists of eight **ovarian tubules** or **ovarioles.** The posterior end of each ovariole is dilated and contains the most mature egg. In front of it is a row of developing eggs, which gradually diminish in size towards the anterior end. The ovarian tubules of each ovary taper anteriorly and unite to form a single thread, which is attached to the tergum. Posteriorly they join to form a wide **oviduct.** The two oviducts proceed backwards, downwards and inwards. They unite to form a median tube, the **vagina or common oviduct**, which runs backwards and opens into the brood pouch at the female genital aperture. The latter is a slit-like aperture and lies on the eighth sternum. There are a pair of small club-shaped sacs, the **spermathecae**, of unequal size. They store sperms received from the male during copulation. The two

spermathecae open by a common duct into the genital chamber on a small **spermathecal papilla.** A pair of large branching **colleterial glands** lie in the last three or four abdominal segments. The left colleterial gland is larger and opaque while the right one is smaller and transparent. The two colleterial glands open into the upper region of the genital chamber by a common aperture. The secretion of these glands provides material for the formation of the egg-case or **ootheca** round a group of eggs.

The 7th, 8th and 9th sterna of the female are modified to enclose a space, the **brood pouch**. The 7th sternum is produced backwards to form a boat-shaped structure, split posteriorly into two parts, the **gynovalvular plates** or **apical lobes**. This structure forms the floor and side walls of the brood pouch. The 8th and 9th sterna form the anterior wall and the roof of the broodpouch respectively. The brood pouch has two regions : the anterior **genital chamber** or **gynatrium** and the posterior **oothecal chamber.**

The genital aperture is surrounded by three pairs of symmetrically arranged, plate-like, chitinous processes, the **gonapophyses**. The latter serve to hold the ova as they are laid and also aid in the formation of an egg-case or ootheca around them. They, thus, act as the **external genitalia** or **ovipositor.**

Copulation. Copulation in cockroach occurs at night in spring and summer. It takes place about a week after the cockroaches become adults, *i.e.*, undergo last mould, and lasts for about an hour and a half. For copulation, the male and female cockroches bring their hind ends close together, the heads facing in the opposite directions. The gonapophyses (phallomeres) of the male open the gynovalvular plates of the female and get interlocked with those of the female. The male genital aperture is brought very near the female's spermathecal papilla on which a spermatophore is deposited by the male. Secretion from the phallic gland cements the spermatophore firmly in position. This secretion hardens to form the outer wall of the spermatophore. After this the two cockroaches separate. During the next day, the sperms from the spermatophore slowly pass into the spermathecae through their aperture. The empty spermatophore then falls off.

Formation of Ootheca. Sixteen eggs usually mature at a time, one in each ovarian tubule. The mature eggs pass into the common oviduct from the left and right sides, alternately. From here they enter the genital chamber of the brood pouch, where they are fertilized by the sperms shed from the spermathecae. The colleterial glands pour on the fertilized eggs their secretion, which hardens to form the egg-case or ootheca. The ootheca is moulded and shaped by the ovipositor and walls of the oothecal chamber. The ootheca (Fig. 12.33) is a dark-brown purse-like capsule, about 9–12 mm. long and 2–3 m.m. thick. It contains

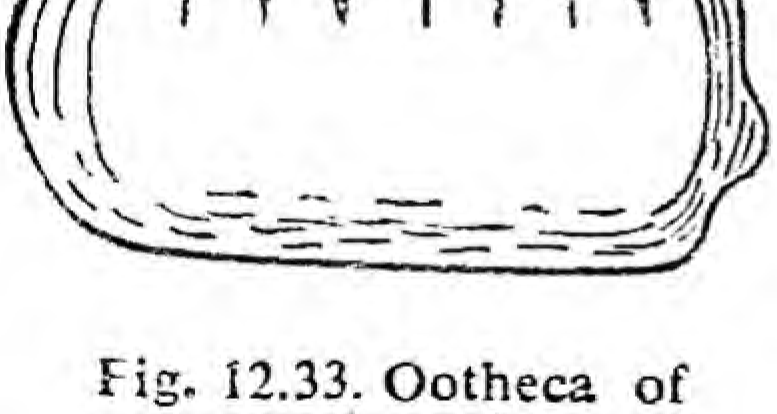


Fig. 12.33. Ootheca of cockroach

16 cigar-like eggs arranged in two rows of eight each. Formation of ootheca takes about a day. The ootheca is carried about by the female in her brood pouch for several days. During this period it protrudes gradually more and more until it is finally deposited at some safe place.

Life-history. The develepmant of the egg occurs inside the ootheca. The young hatching from the ootheca is called the **nymph**. It resembles the adult both in structure and mode of life except that it is smaller in size and lacks wings (Fig. 12.34). It gradually grows into an adult or **imago**. During this period, the nymph sheds its exoskeleton as intervals. This process of changing the exoskeleton is called **moulting** or **ecdysis**. The skin cast off by the nymph is termed **exuviae**. The form of the nymph between two successive moults is known as the **instar**. The egg-case hatches into the **first instar** or **first stage nymph**. It is about a centimetre long and completely lacks the wings. It feeds and grows. After some time, however, its exoskeleton becomes very hard and its growth stops. A new covering is now formed beneath the old one, which is ultimately sloughed off. This is the first moult. It liberates the **second instar** or **second stage nymph**. In the second instar small projections, the **wing-pads**, develop from the posterior margins of the mesothoracic and metathoracic terga. The exoskeleton of the second instar also hardens in due course of time and stops its growth. This is shed and third instar comes out. After each moult, the nymph and its wing-pads grow in size. After the last moult, the wings become fully formed and adult is produced. There are about six or seven moults and an equal number of instars in cockroach. The adult neither grows nor moults. There are three stages in the life-history of cockroach : Egg, nymph and imago. The changes from egg to adult are gradual. They are described as **gradual metamorphosis** or **paurometabolic development**.

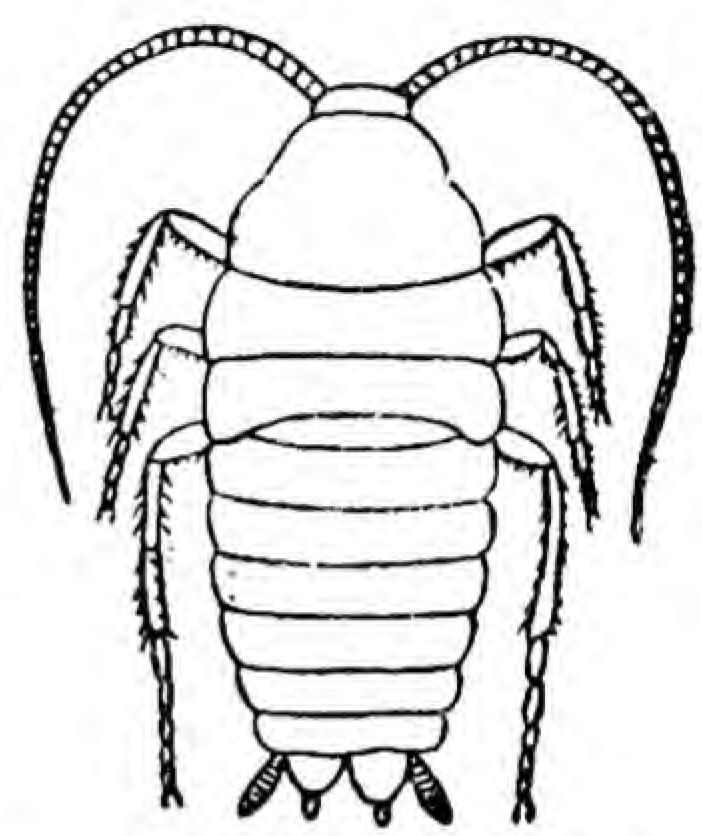


Fig. 12.34. Young nymph

Economic Importance

Cockroaches destroy human possessions like food, clothes, paper, etc. They also spread obnoxious smell in the kitchens. They are eaten in certain parts of the world. They are used as laboratory animals.

Adaptations

Flattend form of its body enables the cockroach to easily slip into narrow spaces. Arrangement and shape of legs make swift running possible in confined places where flight would be of no use. Claws, plantulae and arolia present on the tarsi provide firm grip on all sorts of surfaces so that movement is not impeded. Omnivorous diet ensures enough food everywhere and excludes the necessity of roaming far off from its hiding grounds in search of food. Nocturnal habit and hiding

in narrow inaccessible places during the daytime afford protection from the predators. Removal of nitrogenous waste materials through alimentary canal results in conservation of water by its resorption into the blood. Good degree of sensitivity and living in warm buildings contribute to survival. Laying eggs in oothecae and depositing the latter in small crevices ensure a good deal of safety for the progeny.

Classification

The cockroach described in the preceeding pages is placed in the

Phylum : Arthropoda	Because of having chitinous exoskeleton, distinct head with sense organs and mouth parts, jointed appendages and haemocoel.
Class : Insecta	Because of having three pairs of legs and two pairs of wings.
Sub-class : Pterygota	Due to the presence of wings.
Order : Dictyoptera	Because of chewing mouthparts, thick fore and thin hind-wings, gradual metamorphosis, and jointed cerci.
Family : Blattidae	Because the legs are almost equal-sized and their coxae are large and flattened.
Genus : *Periplaneta*	Because of the possession of wings by both the sexes.
Species : *americana*	Because of relatively light colour and large size (about 32 to 38 mm.).

TABLE 6.

Comparison of Earthworm and Cockroach

Earthworm (*Pheretima posthuma*)	**Cockroach** (*Periplaneta americana*)
I. Habitat	
1. Moist humus-rich soil of gardens, lawns, fields, pastures.	1. Warm food-rich places like kitchens, bakeries, grocery shops, fruit stalls, railway wagons, ships, etc.
II. Habits	
2. Lives in self-dug burrows (fossorial).	2. Lives hidden under various objects.
3. Feeds on dead organic matter (saprozoic).	3. Feeds on both animal and plant matter (omnivorous).

Earthworm	Cockroach
4. Moves about slowly by creeping assisted by setae.	4. Runs fast with legs, rarely flies with wings.
5. Has a good regenerative power.	5. Lacks regenerative power.
III. External Characters	
6. Has long, narrow, cylindrical, moist body measuring about $150 \times 3\text{-}5$ mm.	6. Has ovoid, flattened, dry body measuring about 38×12 mm.
7. Its segmentation is external as well as internal.	7. Its segmentation is only external.
8. Number of segments is variable (100—120).	8. Number of segments is fixed (19).
9. All segments are almost alike and not grouped into regions.	9. Segments are dissimilar and grouped into three regions : **head** of six fused segments bearing appendages, **thorax** of three free segments with appendages, and **abdomen** of ten free apodal segments.
10. There are no appendages.	10. Head bears a pair of antennae, labrum, a pair of mandibles, a pair of maxillae, labium and hypopharynx. Thorax carries 3 pairs of legs and 2 pairs of wings. Abdomen bears a pair of cerci in both sexes and a pair of analstyles in males.
IV. Body-wall	
11. Body-wall consists of 5 layers : cuticle, epidermis, basement membrane, musculature, and coelomic epithelium.	11. Body-wall consists of 3 layers : cuticle, epidermis and basement membrane.
12. Cuticle is thin and soft, lacks spines.	12. Cuticle is very thick and hard, forms tough exoskeleton, bears immovable spines.
13. Epidermis has mucous and albumen cells.	13. Epidermis is without such cells.
14. A ring of minute, f-shaped, movable, chitinous setae is embedded in the body-wall in the middle of each segment except the first and the last.	14. Fine, hair-like, movable setae are scattered over the body. These are prolongations of special cells in the epidermis.

Earthworm	Cockroach
15. Setae aid in locomotion.	15. Setae are tactile organelles.
V. Muscles	
16. Muscles form a complete cylinder around the body and are not attached to the cuticle.	16 Muscles occur in bundles as in vertebrates and are attached to the inner surface of the exoskeleton.
17. All muscles are smooth.	17. All muscles are striated.
VI. Coelom	
18. True coelom is spacious, surrounds the viscera and is lined by coelomic epithelium.	18. True coelom is reduced to cavities within reproductive organs.
19. There is no haemocoel.	19. Haemocoel is spacious and surrounds the viscera. It is not lined by coelomic epithelium.
20. Coelom contains a milky coelomic fluid.	20. Haemocoel is full of colourless blood.
21. Coelomic fluid contains four types of cells : phagocytes, circular cells, chloragogen cells and mucocytes.	21. Blood contains two types of corpuscles : proleucocytes and leucocytes.
22. Coelom is divided by vertical septa into a series of chambers.	22. Haemocoel is divided by two horizontal diaphragms into three sinuses : dorsal, middle and ventral.
23. Coelom communicates with the exterior by dorsal pores.	23. Haemocoel does not communicate with the exterior.
24. Coelomic fluid oozes out through dorsal pores.	24. Blood does not ooze out.
25. Coelom contains lymph glands lying over the intestine from the 26th segment onward.	25. Haemocoel contains a good deal of adipose tissue over the viscera.
VII. Digestive System	
26. Alimentary canal is straight, as long as the body and is connected to the body-wall by septa.	26. Alimentary canal is coiled, longer than the body and without connections with the body-wall.
27. Alimentary canal is not differentiated into regions and comprises mouth, buccal cavity, pharynx, oesophagus, gizzard, stomach, intestine and anus.	27. Alimentary canal is differentiated into three regions : the **fore-gut** comprising pre-oral cavity, mouth, pharynx, oesophagus, crop and gizzard, the **midgut** and the **hind-gut** including ileum, colon and rectum.

Earthworm	Cockroach
28. Mouth faces forward and is overhung by a fleshy prostomium.	28. Mouth faces downwards and is surrounded by movable mouth parts.
29. There is no pre-oral cavity.	29. Mouth parts enclose a pre-oral cavity containing opening of salivary duct.
30. Pharynx is a horizontal sac with lateral walls deeply invaginated.	30. Pharynx is a vertical tube, circular in cross section.
31. Oesophagus is fairly long.	31. Oesophagus is very short and narrow.
32. There is no crop.	32. A large crop follows the oesophagus.
33. Gizzard is lined by cuticle which is smooth and does not project into the stomach.	33. Gizzard is lined by cuticle which is produced into teeth and bristles and projects into the mid-gut.
34. Intestine has a pair of short, conical caeca along its course in the 26th segment.	34. Mid-gut has 6-8 long, finger-like caeca at its beginning.
35. Rectum is not distinguishable externally.	35. Rectum is distinguishable externally.
36. Anus is without podical plates.	36. Anus opens between two podical plates.
37. Alimentary canal is covered by coelomic epithelium.	37. There is no coelomic epithelium over the alimentary canal.
38. The longitudinal muscles are external to the circular muscles in the gut-wall.	38. The longitudinal muscles are internal to the circular muscles in the gut-wall.
39. Digestive glands include the buccal mass and lining of stomach and intestine.	39. Digestive glands include salivary glands, hepatic caeca and lining of mid-gut.
40. No peritrophic membrane is formed around the food.	40. A thin, permeable, chitinous peritrophic membrane is formed around the food in the mid-gut.

VIII. Respiratory System

Earthworm	Cockroach
41. Respiration is cutaneous.	41. Respiration is tracheal.
42. Blood plays an important role in respiration. It carries	42. Blood plays no role in respiration. Branching tracheae

Earthworm	Cockroach
oxygen from the skin to the tissues and carbon dioxide from the latter to the skin.	carry air directly to the tissues through spiracles.
43. Respiration has 2 phases : external in skin and internal in tissues.	43. Respiration has only one phase, *i.e.* internal in tissues.
44. No special respiratory movements take place.	44. Special respiratory movements comprising alternate expansion and contraction of the abdomen occur to draw in and expel out air.
45. Carbon dioxide is wholly lost by diffusion through the skin	45. Carbon dioxide is lost partly by diffusion through the body-wall and partly via tracheae.
IX Nervous System	
46. Nerve-ring surrounds the pharynx.	46. Nerve-ring surrounds the oesophagus.
47. Brain is formed by the fusion of a pair of ganglia.	47. Brain is formed by the fusion of 3 pairs of ganglia.
48. Subpharyngeal ganglion represents a pair of fused ganglia.	48. Suboesophageal ganglion represents 3 pairs of fused ganglia.
49. Circumpharyngeal connectives are slender threads.	49. Circumoesophageal connectives are broad bands.
50. Nerve-cord extends the entire length of the body.	50. Nerve-cord extends up to the 7th abdominal segment.
51. There is a segmental ganglion in each segment.	51. Fifth and last three abdominal segments lack segmental ganglia.
52. All segmental ganglia are alike.	52. Thoracic and last abdominal ganglia are larger than others.
53. Brain gives off on each side 2 nerves : prostomial and buccal.	53. Brain gives off on each side 3 nerves : optic, antennary and labrofrontal.
54. Each peripharyngeal connective gives off 2 nerves to the first two segments.	54. No nerves arise from the circum-oesophageal connectives.
55. Subpharyngeal ganglion gives off on each side 2 nerves to 3rd and 4th segments.	55. Suboesophageal ganglion gives off on each side 3 nerves : mandibular, maxillary and labial.

Earthworm	Cockroach
56. Each segmental ganglion gives off 3 pairs of nerves.	56. Each thoracic ganglion gives off several nerves while each abdominal ganglion gives off only one pair of nerves except the last that gives off 3 pairs of nerves.
57. Nerves arising from the segmental ganglia innervate their own segments.	57. Nerves arising from the segmental ganglia usually innervate the next posterior segment.
X. Sense Organs	
58. Organs for all the popular senses except for hearing are present.	58. Organs for all the five popular senses are present.
59. All sense organs are simple, the photoreceptors are unicellular, those for touch, smell and taste are small groups of sensory cells.	59. All sense organs are simple and unicellular. The compound eyes are multicellular and very complex.
XI. Circulatory System	
60. Circulatory system is of closed type.	60. Circulatory system is of open type.
61. There are four pairs of loop-like heart with valves and lying lateral to the gut.	61. There is a single tubular heart with valves and ostia and lying dorsal to the gut.
62. There are several main vessels, which give off or receive smaller vessels that in turn branch into or are formed by union of capillaries.	62. There is a single main vessel, the **anterior aorta**, that arises from the heart and opens into the head sinuses. No smaller vessels and capillaries are present.
63. Blood is red due to the presence of a respiratory pigment, **haemoglobin**.	63. Blood is colourless, being without respiratory pigment.
64. Blood corpuscles are all alike.	64. Blood corpuscles are of two types : proleucocytes and leucocytes.
XII. Excretory System	
65. Excretory organs are innumerable, microscopic **nephridia**.	65. Excretory organs are numerous, fine but quite long, yellowish, thread-like **Malpighian tubules.**
66. Nephridia are highly complex in structure.	66. Malpighian tubules are simple straight tubes.

Earthworm	Cockroach
67. Nephridia are scattered throughout the body.	67. Malpighian tubules lie in a bundle attached to the ileum.
68. Nephridia are of three types : septal, integumentary and pharyngeal.	68. All Malpighian tubules are alike.
69. Septal and pharyngeal nephridia open into the gut, integumentary to the exterior.	69. All Malpighian tubules opens into the ileum.
70. Septal nephridia open into the coelom also.	70. No Malpighian tubule opens into the haemocoel.
71. Excretory matter is chiefly urea.	71 Excretory matter consists of uric acid salts.
72. No excretion occurs by storage.	72. Some excretion also occurs by storage of waste matter in the fat cells.
XIII Reproductive System	
73. Earthworm is bisexual.	73. Cockroach is unisexual.
74. There are two pairs of testes.	74. There is a single pair of testes.
75. Testes are minute, palmate enclosed in testis-sacs and ventral to the gut.	75. Testes are fairly large, lobular, uncovered and dorsal to the gut.
76. Testes become functional in the adult worm.	76. Testes become functional in the young insect and disappear in the adult.
77. There are two pairs of vasa deferentia, each starting as a spermiducal funnel just behind its testis.	77. There are only a pair of vasa deferentia, which are continuous with the testes and lack spermiducal funnels.
78. Vasa deferentia do not meet, open out by a pair of male genital apertures on the ventral side of 18th segment.	78. Vasa deferentia join to form an ejaculatory duct that opens out at the hind end of the body.
79. There are a pair of large prostate glands and two pairs of small accessory glands.	79. There are no prostate and accessory glands.
80. Mushroom-shaped and conglobate glands are absent.	80. Mushroom-shaped and conglobate glands are present.
81. Ovaries are minute, palmate, and ventral to the gut.	81. Ovaries are large and dorsal to the gut.

Earthworm	Cockroach
82. Oviducts are very short, each with an oviducal funnel just behind the ovary.	82. Oviducts are fairly large continuations of the ovarioles without oviducal funnels.
83. Oviducts join and immediately open out on the ventral side of the 14th segment.	83. Oviducts join to form the vagina which opens out at the hind-end of the body.
84. There are four pairs of similar spermathecae, each opening out individually at the ventro-lateral parts of the annuli between 5/6, 6/7, 7/8 and 8/9 segments.	84. There are only a pair of unequal spermathecae that open out together at the hind-end of the body close to the genital aperture.
85. There are no colleterial glands.	85. There are a pair of colleterial glands.
86. There is no brood pouch.	86. Female has a brood pouch at her hind end.
XIV Copulation	
87. Copulation takes place in head-to-tail position.	87. Copulation takes place in tail-to-tail position.
88. Both the copulants get inseminated.	88. Only the female is inseminated.
XV. Ootheca Formation	
89. Ootheca is formed around the clitellum, first receives the ova and then the sperms.	89. Ootheca is formed in the brood pouch around both ova and sperms simultaneously.
90. Ootheca deposited in the soil as soon as formed.	90. Ootheca kept in the brood pouch for several days before depositing it in some hole or crevice.
XVI. Development	
91. The young worm hatching from the ootheca exactly resembles the adult worm.	91. The young insect hatching from the ootheca differs from the adult in lacking wings.
92. Growth of the young is a continuous process without moulting.	92. Growth of the nymph occurs at intervals after each moult.
XVII. Economic Importance	
93. Earthworm is a useful animal.	93. Cockroach is a harmful insect.

TEST QUESTIONS

1. Describe the external characters of cockroach. What is the zoological name and systematic position of this animal?

2. Give an account of the digestive system of cockroach. What is the food of this insect and how is it taken ?

3. How will you distinguish between male and female cockroach ? Describe the reproductive system of any of them.

4. How do the followiug processes occur in cockroach ?

(*a*) Locomotion (*b*) Respiration (*c*) Ootheca formation

(*d*) Copulation (*e*) Excretion.

5. Make a labelled sketch of the front view of the head of cockroach.

6. Give an account of the mouth-parts of cockroach.

7. How do *Pheretima* and *Periplaneta* differ from each other with regard to the coelom and blood ?

8. Give a brief description of the nervous system of cockroach and compare it with that of earthworm.

9. What do you understand by the following terms ?

Omnivorous animal, Gonapophyses, Tegmina, Nocturnal creature, Stigmata.

10. Discuss the economic importance of cockroach. Name the more common species of this animal and bring out differences between them.

CHAPTER 13

Oryctolagus cuniculus

(The Rabbit)

NATURAL HISTORY

The **rabbit**, formerly called **cony** (or **coney**), has been selected from the mammals for detailed study because it is quite a good representative of this group and also of the vertebrates in general, is clean and harmless, has a large size convenient for dissection, is easily available and can be kept without much effort.

Zoological Name and Systematic Position. The rabbit and the hare look very similar and both are called "**Khargosh**" in vernacular. They were earlier placed in the same genus, viz. *Lepus*. Now, however, they are known to differ in several important respects (see chapter 36), Consequently, the rabbit has been assigned a new genus *Oryctolagus* and the genus *Lepus* has been reserved only for the hare. The full zoological name of the common rabbit is *Orcytolagus cuniculus* and that of the common hare is *Lepus ruficaudatus*.

Formerly, the rabbit was included in the order **Rodentia** because of its rodent-like teeth. Recently, however, it has been found to differ from the rodents in certain skeletal, seriological and some other features. This has necessitated the creation of a new order **Lagomorpha** for the rabbit. Detailed classification of rabbit is given in chapter 25.

Geographical Distribution. The rabbit is now almost a cosmopolitan animal. Its original home is the Spanish Peninsula, Southern France, Algiers, North Africa and some of the Mediterranean Islands. It has been imported into other parts of the world where it has readily acclimatised itself. In Australia and New Zealand, for want of natural enemies, it has multiplied beyond bounds and has become a serious nuisance. Its domestication, which was probably started by the Romans in Spain long ago, has brought forth a number of varieties which differ from the wild form chiefly in the colour, size and texture of the fur.

Habitat. The habitat, *i.e.* natural home, of rabbit is the vicinity of grasslands and open woodlands.

Habits. The noteworthy habits of rabbit are locomotion, burrowing, fee ding and breeding.

Locomotion. Locomotion in rabbit is by leaping. Preparatory to a leap, the animal arches its body and bends the hind-limbs to place them

a bit ahead of the fore-limbs. Now pressing the ground downwards, the body and the hind-limbs are suddenly straightened. This forces the animal forward through the air like an arrow. On the completion of the leap, fore-limbs meet the ground first, serving to absorb the pressure with which the animal falls down. Soon the hind-limbs are again drawn ahead of the fore-limbs to take another leap.

The rabbit in the wild state can cover 32—40 kilometres per hour.

The rabbit shows some structural modifications to suit its mode of locomotion. The centre of gravity in the normal resting position is far back, being nearly between the hind-limbs. Large area of the feet in contact with the ground and long segments of the hind-limbs bent like a spring (z) increase the thrust produced by straightening of the hind-limbs. To transmit this thrust to the axis of the body, the pelvic girdle lies parallel to the vertebral column and is fused with the sacrum. To reduce the shock of landing on the ground after a leap, the short but stout fore-limbs have a bend at the elbows, the hands touch the ground with the digits only and the pectoral girdle is springy.

Burrowing. The rabbit is a **fossorial** animal, *i.e.* it lives in self-dug burrows. For the preparation of a burrow, the fore-limbs scratch the earth and the hind-limbs throw it back. Horny claws over the tips of the digits greatly facilitate this process. The burrow often has several side passages and may have more than one outlet. It is called the **warren.**

Feeding. The rabbit is **herbivorous** in diet. It usually feeds on grass but tender field crops like cereals, vegetables like turnips, carrots and lettuce, young trees and certain fruits are also eaten. For the purpose of feeding and playing, rabbits move about at twilight in groups. They are, thus, **crepuscular** and **gregarious** animals.

An interesting feature in the feeding of rabbit is its habit of **refection** or **coprophagy**, *i.e.* passing the food twice through the alimentary canal. It eats its night droppings without masticating them. These contain vitamins and simplified cellulose.

Breeding. The rabbit is **polygamous,** *i.e.* one male lives in the company of many females. It has a high rate of fertility and breeds all the year round. The peak mating, however, extends from January to June. The female starts bearing young ones at the age of six months and produces 6—8 litters in a year, each litter comprising 3—8 young ones.

The mother shows a good deal of **parental care.** Before the birth of young ones, she lines the burrow with dry grass over which she prepares a warm bed out of hair pulled from her own body with the mouth. The young ones are then gently deposited on this warm bed which usually lies at the farther end of the burrow. At the time of birth, the young ones are essentially like the parents except that they are very weak, hairless, deaf and blind. They are looked after and nursed by the mother on her milk till they become strong enough to look after themselves. They are usually weaned at less than one month. While going out for

feeding, the mother closes the outlet of the burrow. If threatened by some enemy, the mother is known to transfer the young ones, holding one by one in her mouth, to a safe place at night.

The rabbit normally enjoys an average age of about eight years provided it is spared by diseases and its enemies.

Enemies. The rabbit is attacked by a number of enemies which come from two main groups : the **carnivorous mammals** like cats, dogs and foxes and the **birds of prey** like owls, eagles and hawks. Its gregarious, fossorial and crepuscular nature goes a long way in protecting it from its enemies. On seeing an enemy, it thumps its hind-limbs on the ground to produce a warning sound, hearing which all run to safety. Man may also be included among the enemies of rabbits as he takes quite a heavy toll of them for fur, meat, sport and dissection work

Economic Importance. The rabbit has something both for and against it. It damages crops and vegetables ; befouls the grass in the meadows with its excreta ; and serves as a carrier of some human parasites. On the other hand, it provides a good fur for gloves, purses, hats, etc. ; yields palatable meat ; serves as a good sport for the hunters ; and forms a nice laboratory animal for biological and medical investigations. It also furnishes livelihood to many who are engaged in its trade.

TEST QUESTIONS

1. Give the zoological name and economic importance of rabbit. Why is this animal studied as a type from the class Mammalia ?

2. What is the habitat of rabbit ? Write brief notes on the following habits of this animal—Feeding, Breeding and Locomotion.

3. Explain the following terms giving at least two examples in each case—

(*a*) Fossorial Animals.
(*b*) Viviparous and Oviparous Animals.
(*c*) Crepuscular Animals.
(*d*) Gregarious Animals.

CHAPTER 14

Oryctolagus cuniculus

(The Rabbit)

3537

EXTERNAL CHARACTERS

The rabbit is a **quadruped** as it uses all the four of its limbs during locomotion. It shows **bilateral symmetry.** The whole surface of its body is covered with short, soft, close-set **hair** or **fur.** The hairy coat helps in keeping the body temperature constant at about 101·8°*F* (38·8°*C*) by preventing the undue loss of heat. The rabbit is, thus, a **warm blooded** or **homoeothermal** animal. The hair contain pigments which impart colour to the animal. The domestic varieties are usually white or black and white. The wild rabbit is dust-brown with a white patch under the tail. The dust brown colour matches with the surroundings of the wild rabbit and makes it almost invisible. This is known as the **protective colouration.** The significance of the white patch under the tail is controversial. It is usually thought to be a signal to other rabbits that immediate departure is called for.

The body of rabbit consists of four regions : **head, neck, trunk and tail.** The trunk bears two pairs of **limbs** : fore and hind.

1. **Head.** The head makes an angle with the rest of the body and bears the **mouth** at its lower or anterior end. The mouth is a relatively small transverse slit and is bounded by two soft, movable, hairy **lips :** upper and lower. The upper lip is divided by a median vertical cleft into right and left halves and is called the **harelip.** The cleft connects the mouth with the **external nares** above and leaves the front upper teeth (incisors) exposed. The external nares are oblique, oval slits lying under fleshy tip of the snout which is required to be raised for examining them. Some distance above (behind) the nares are a pair of very prominent **eyes.** They are laterally placed towards the upper side of the head to make the animal more watchful of its enemies. Each eye has three eyelids : the **upper**, the **lower** and the **nictitating membrane.** The upper and lower eyelids are movable and fringed with a few hair of **eyelashes.** The nictitating membrane is an opaqe, white, hairless fold of skin lying in the anterior angle or **canthus** of the eye within the other eyelids. It can be drawn across the eyeball to clean it. Further above (behind), the head bears a pair of long, movable, trumpet-shaped projections called the **pinnae.** They are usually held vertically with the concavity directed outwards and somewhat forwards. They enclose the

external auditory canals. The pinna and the external auditory canal together form the external ear, a structure not found in vertebrates other than mammals. Long, stiff, sensory hair, called the **vibrissae** or

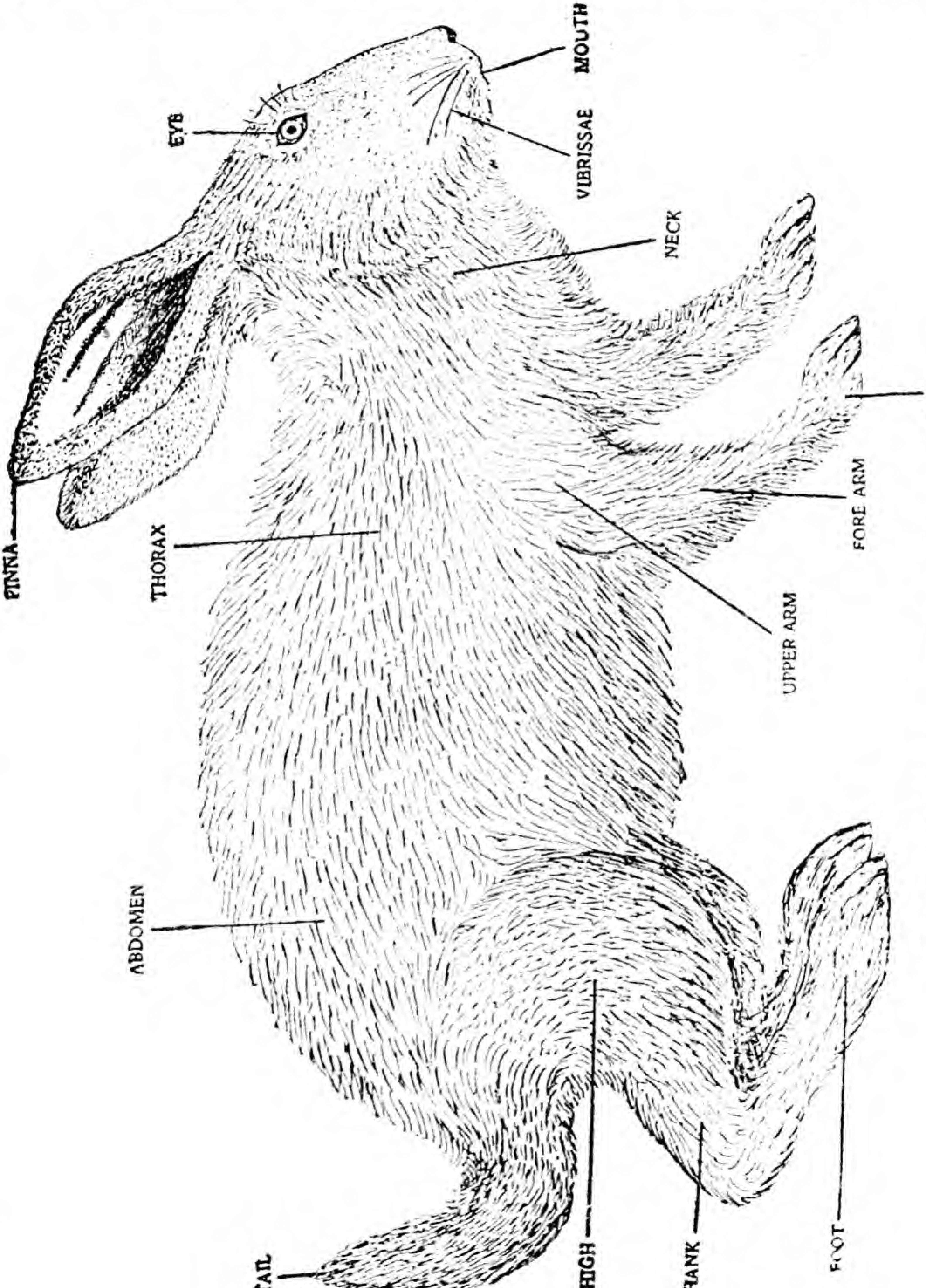


Fig. 14.1. The rabbit—external characters

whiskers, are present at the sides of the snout and above and below the eyes. They act as tactile organs. The length of the whiskers of the two sides taken together is more than the width of the body. They enable the animal to determine whether or not it would be able to pass through a certain passage.

2. Neck. The neck connects the head with trunk. It is narrow and fairly short in rabbit, probably because of the laterally placed eyes which can see all round without turning the head. The neck, however, permits the animal to turn its head about.

3. Trunk. The trunk is somewhat cylindrical. It has two regions : the anterior narrow chest or **thorax** enclosed by ribs and posterior broader belly or **abdomen** which is soft. The female bears four or five pairs of small outgrowths, the **teats** or **mammae**, arranged at intervals on the ventral surface of thorax and abdomen. They are perforated by openings of ducts of **milk** or **mammary glands** and are used to feed the young ones for some time after birth. The teats occur in the males also but in vestigial condition.

(*i*) **Apertures.** There are two apertures at the hind end of the trunk : the **anus** and the **urinogenital aperture**. The anus is an outlet for the alimentary canal and lies below the base of the tail. The urinogenital aperture lies a little in front of the anus. In the male, it is situated at the tip of a cylindrical structure, the **penis**. The penis is enclosed in a fold of loose skin, the **prepuce**. On either side of the penis, there is an oval pouch of skin, the **scrotal sac**, lodging the testis. The urinogenital aperture in the female is slit-like and is known as **the vulva**, At the anterior margin of the vulva there is a rod-like body, the **clitoris**, which is homologous to the penis of the male. A pair of hairless depressions is seen on the sides of the anus but a little in front of it. These are called the **perineal pouches**. Each pouch contains a papilla on which opens the **perineal gland**. The secretion of the perineal glands imparts characteristic odour to the animal.

(*ii*) **Limbs.** The limbs are vertical in position to hold the body clear of the ground. They serve for locomotion. Both the limbs have the general pentadactyle plan. The fore-limbs are, however, much shorter than the hind-limbs.

(*a*) **Fore-limb.** A fore-limb consists of three parts : the **upper-arm** or **brachium**, the **fore-arm** or **ante-brachium** and the **hand** or **manus**. When at rest, the upper-arm is directed backwards and the fore-arm and the hand forward. The upper-arm is closely applied against the side of the body and is almost completely hidden by the skin. The hand further consists of the **wrist** or **carpus**, the **palm** or **metacarpus** and five **fingers** or **digits**. Beginning from the medial side, the digits of the hand are described as the first or **pollex** (thumb), the second or **index**, the third or middle, the fourth and the fifth All the fingers end in sharp, curved, horny **claws**. Besides helping in locomotion, the fore-limbs form the chief digging organs.

(*b*) **Hind-limb.** A hind-limb is also divisible into three parts ; the

proximal **thigh** or **femur**, the middle **shank** or **crus** and the distal **foot** or **pes**. When at rest, the thigh is directed forwards, the shank backwards and the foot again forwards. Like the upper arm, the thigh is also almost hidden by the skin. The foot is composed of the **ankle** or **tarsus**, **instep** or **sole** or **metatarsus** and four **toes** or **digits**. The first digit or **hallux**, corresponding to the human great toe, is absent. All the digits of the hind-limb are also furnished with claws. The palms and soles are both hairy.

4. Tail. The tail is very short and curved upwards usually.

TEST QUESTION

1. Give an account of the external characters of rabbit.

CHAPTER 15

Oryctolagus cuniculus

(The Rabbit)

BODY-WALL, COELOM AND VISCERA

1. Body-wall. Body of rabbit is covered with **skin** which, as already stated, bears soft hair or fur all over. Beneath the skin is a layer of **muscles** (Fig. 15.1). This layer is thicker on the dorsal side than elsewhere. The muscular layer is covered internally by flat cells or squamous epithelium known as the **peritoneum**. The skin, muscular layer and peritoneum collectively form the **body wall**. The latter forms a protective wrapper for the delicate internal organs. Besides this, the skin acts as a sensory, excretory, secretory and heat-regulatory organ ; the muscular layer develops supporting frame-work of bones ; and the peritoneum secretes coelomic fluid.

The thick muscles of the dorsal side contain the backbone or **vertebral column**. The latter encloses a cord of nervous tissue, the **spinal cord**. The muscles of thorax have breast-bone or **sternum** in the mid-ventral line and **ribs** or **costae** laterally. The backbone, breast-bone and ribs are joined to form a bony case (Fig. 1 5.1). The head contains the **skull** which surrounds the **brain** (Fig. 15.3). The skull is connected with the vertebral column and the brain with the spinal cord. The muscles at the anterior and posterior parts of the trunk enclose the **shoulder** or **pectoral** and **hip** or **pelvic girdle** respectively. The girdles provide articulation to the limb bones which are embedded in the limb muscles.

2. Coelom. The body-wall encloses a spacious cavity in the trunk. It is known as the **body-cavity** or **coelom**. It contains most of the internal organs and is divided into two compartments : the anterior smaller **thoracic cavity** and the posterior larger **abdominal cavity**, by a vertical muscular partition, the **diaphragm** (Fig. 15.3). The diaphragm, in the position of rest, is convex anteriorly to project into the thoracic cavity.

The thoracic cavity contains in it two smaller air-tight cavities, the **pleural cavities** (Fig. 15.1), housing the lungs that completely fill them. The wall of the pleural cavity consists of two layers of peritoneum known as the **pleura**. The inner layer or the **visceral pleuron** closely invests the lung while the outer layer or the **parietal pleuron** lines the thoracic cavity. The two pleura are continuous with each other over the bronchi. Since the lungs remain fully distended during life,

the parietal and visceral pleura lie very close to each other. The very narrow space between the two pleura contains the coelomic fluid that permits them to slip over each other easily. The space between the two pleural cavities is called the **mediastinal space.** The dorsal part of the mediastinal space is narrow and contains the oesophagus, trachea and main blood-vessels ; while the ventral part is wider and houses the heart. The heart is enclosed in the **pericardium** which consists of two layers, the **visceral** and **parietal peritoneum**, with coelomic fluid between the two.

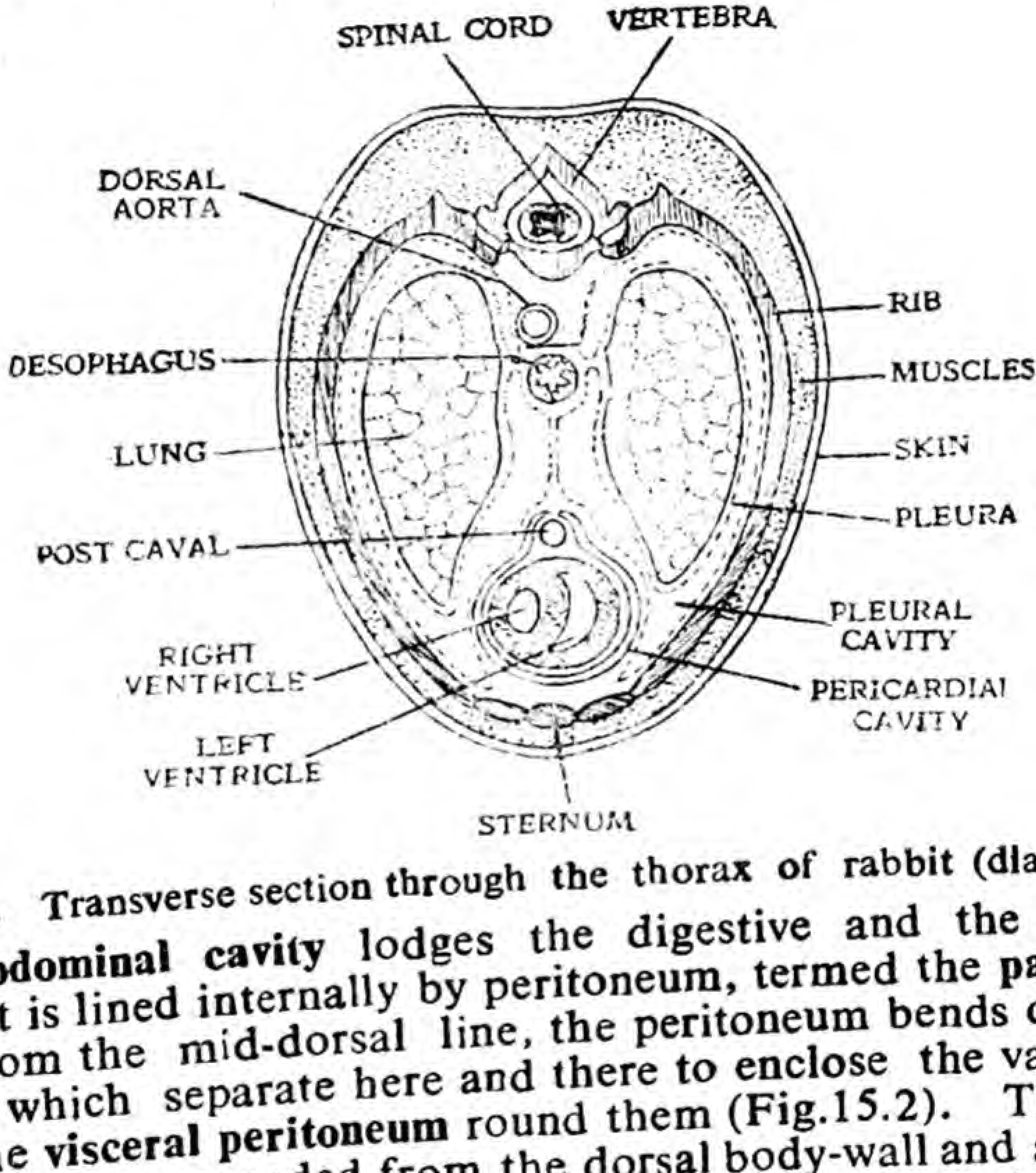


Fig. 15.1. Transverse section through the thorax of rabbit (diagrammatic)

The **abdominal cavity** lodges the digestive and the urinogenital organs. It is lined internally by peritoneum, termed the **parietal peritoneum**. From the mid-dorsal line, the peritoneum bends downwards as two folds which separate here and there to enclose the various organs, forming the **visceral peritoneum** round them (Fig.15.2). The abdominal organs are, thus, suspended from the dorsal body-wall and are connected with one another by double folds or reflections of peritoneum. The double fold of peritoneum is known as the **mesentery** when it suspends an organ or viscus (singular of viscera) from the dorsal body-wall, as the **omentum** when it connects the stomach with some other internal organ, *e.g.* gastroduodenal omentum between the stomach and the duodenum, and as the **ligament** when it joins any two internal organs other than the stomach, *e.g.* hepatoduodenal ligament between the liver and the duodenum. The mesentery attaching the stomach, intestine, rectum, testis, ovary and oviduct to the dorsal body-wall is distinguished as **mesogastrium, mesentery proper, mesorectum, mesorchium, mesovarium** and **mesosalpinx** respectively. The kidneys project into the abdominal cavity from the dorsal body-wall, pushing the peritoneum before them. They are, thus, covered by the peritoneum on the ventral side only and are said to be retroperitoneal. The abdominal organs appear to lie in the coelom and

are generally described as such. Actually, however, they are outside it, being separated from it by visceral peritoneum. The abdominal coelom

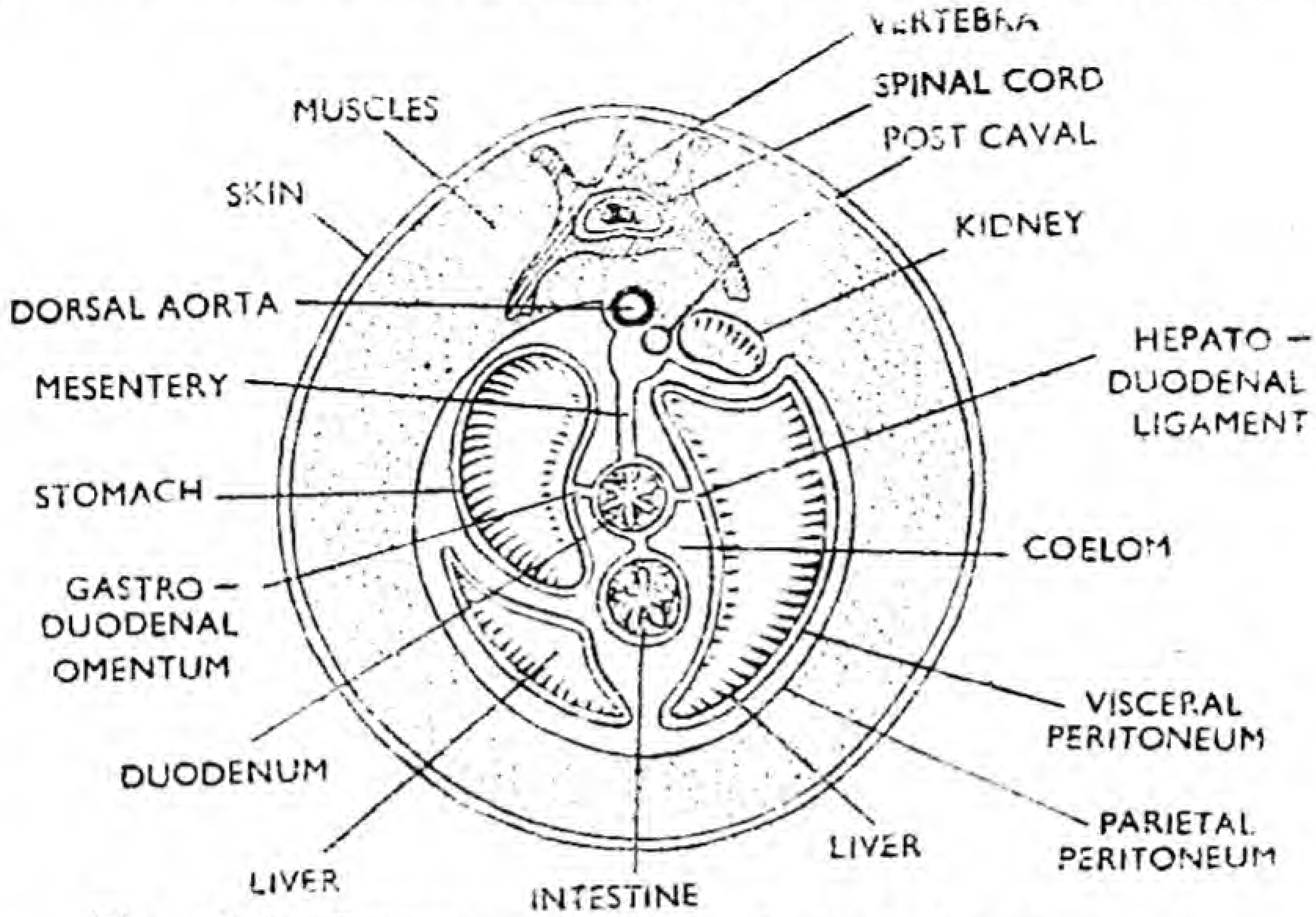


Fig. 15.2. Transverse section through the abdomen of rabbit (diagrammatic)

also contains a watery coelmic fluid. It keeps the surface of the internal organs moist so that they can slide over one another easily without any friction and injury.

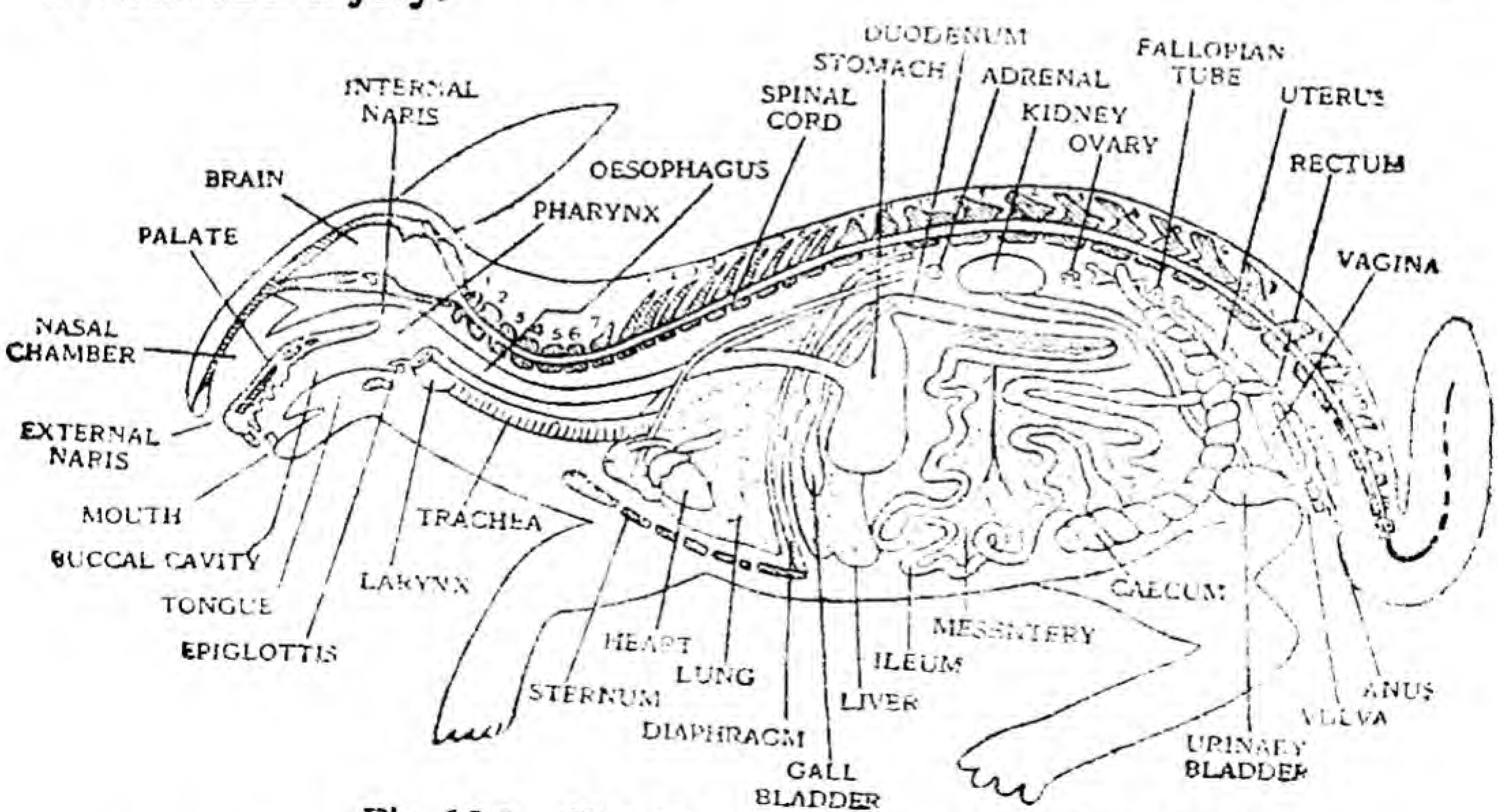


Fig. 15.3. The internal organs or viscera of rabbit

The **neck** only contains the oesophagus, trachea and blood-vessels. It lacks coelom and organs. The coelom and organs are also absent in the tail and legs.

3. Viscera. The soft internal organs are collectively called the **viscera.** The latter include the heart, lungs, stomach, liver, intestine, pancreas,

spleen, urinary bladder, kidneys and gonads (Fig. 15.3). Of these, the heart and the lungs alone lie in the thoracic cavity. All others are in the abdomen. These organs are grouped into a number of systems corresponding to the main activities of the animal. The various systems with their main parts and important functions are listed below :—

TABLE 7

S.No.	System	Parts	Function
1.	Integumentary	Skin and its derivatives	Sensory, protective, excretory, etc.
2.	Muscular	Muscles	Movement
3.	Skeletal	Bones and cartilages	Supporting and protective.
4.	Digestive	Alimentary canal and Digestive glands	Digestion and absorption of food.
5.	Respiratory	Trachea and lungs.	Exchange of CO_2 and O_2.
6.	Circulatory	Heart, blood-vessels and blood.	Transport of food, gases, wastes and hormones.
7.	Lymphatic	Lymph nodes, lymph vessels, lymph.	Exchange of materials between blood and tissues.
8.	Nervous	Brain, spinal cord, nerves, sense organs.	Reception of and response to stimuli.
9.	Urinogenital	Kidney and gonads with their ducts.	Excretion and reproduction.
10.	Endocrine	Ductless glands.	Secretion of hormones.

TEST QUESTIONS

1. What do you understand by the words 'organs' and 'system'? Name the various systems of an animal body. Give the main parts and functions of each system.

2. Make neat and labelled sketches of the transverse section through the thorax and abdomen of rabbit showing the relative position of the main viscera and their relation to the peritoneum.

3. Explain the following terms :
Viscera, Coelom, Pleura, Pericardium, Mesentery, Diaphragm.

CHAPTER 16

Oryctolagus cuniculus

(The Rabbit)

INTEGUMENTARY SYSTEM

The integumentary system consists of the **integument** or **skin** and the structures derived from it, like the hair, glands and claws.

I. Skin

The skin consists of two regions : the outer thin **epidermis** and the inner thick **dermis** or **corium**, the two fitting into each other by a system of ridges and depressions (Fig. 16.1).

1. Epidermis. The **epidermis** develops from the ectoderm of the embryo. It is a **stratified epithelium**, *i. e.* it is formed of several layers of cells. The innermost layer consists of columnar cells and is known as the **Malpighian layer** or **stratum germinativum.** It lies on a basement membrane secreted by the underlying dermis. The cells of this layer are very active and divide by mitosis to produce new cells. The newly-formed cells pass outwards and become progressively flattened. The region of epidermis where this occurs forms the **transitional layer.** In the transitional layer, the cytoplasm of the cells is slowly replaced by a very hard, tough, insoluble protein, the **keratin** or **horn.** By the time the cells reach the surface of the epidermis they become extremely thin and completely dead. They are said to constitute the **horny layer** or **stratum corneum.** This layer is protective in function. It is cast off as thin pieces at intervals and is replaced from beneath. The rate of formation of new cells at the bottom of the epidermis is approximately the same as that at which the surface cells are cast off. This keeps the thickness of the epidermis more or less constant. There are practically no blood-vessels and nerves in the epidermis so that no bleeding or pain results if only the epidermis is injured. The outer surface of the epidermis is beset with numerous minute pores of sweat glands and hair-follicles.

Where the skin is thick, *e g.* palms and soles, the transitional layer of the epidermis shows two regions : the inner **stratum granulosum** of granular cells and the outer **stratum lucidum** of clear hyaline cells.

2. Dermis. The dermis develops from the mesoderm of the embryo. It consists mainly of dense connective tissue and is about 2 or 3 times as thick as the epidermis. It contains interlacing bundles of **white collagen fibres**, a network of **yellow elastic fibres** and various types of cells like **fibroblasts, histiocytes** and **mast cells.** The white fibres serve to

attach the skin firmly to the body and limit its stretching. The yellow fibres cause recovery of the skin after its stretching. The fibroblasts secrete the fibres. The histiocytes eat up the foreign particles entering the skin. The mast cells secrete the **matrix** in which all other structures are embedded. The dermis also contains numerous blood-vessels with clusters of capillaries abutting on the epidermis, nerve-fibres ending in tactile corpuscles beneath the epidermis and lymph-vessels. Some muscle-fibres are also present in the dermis.

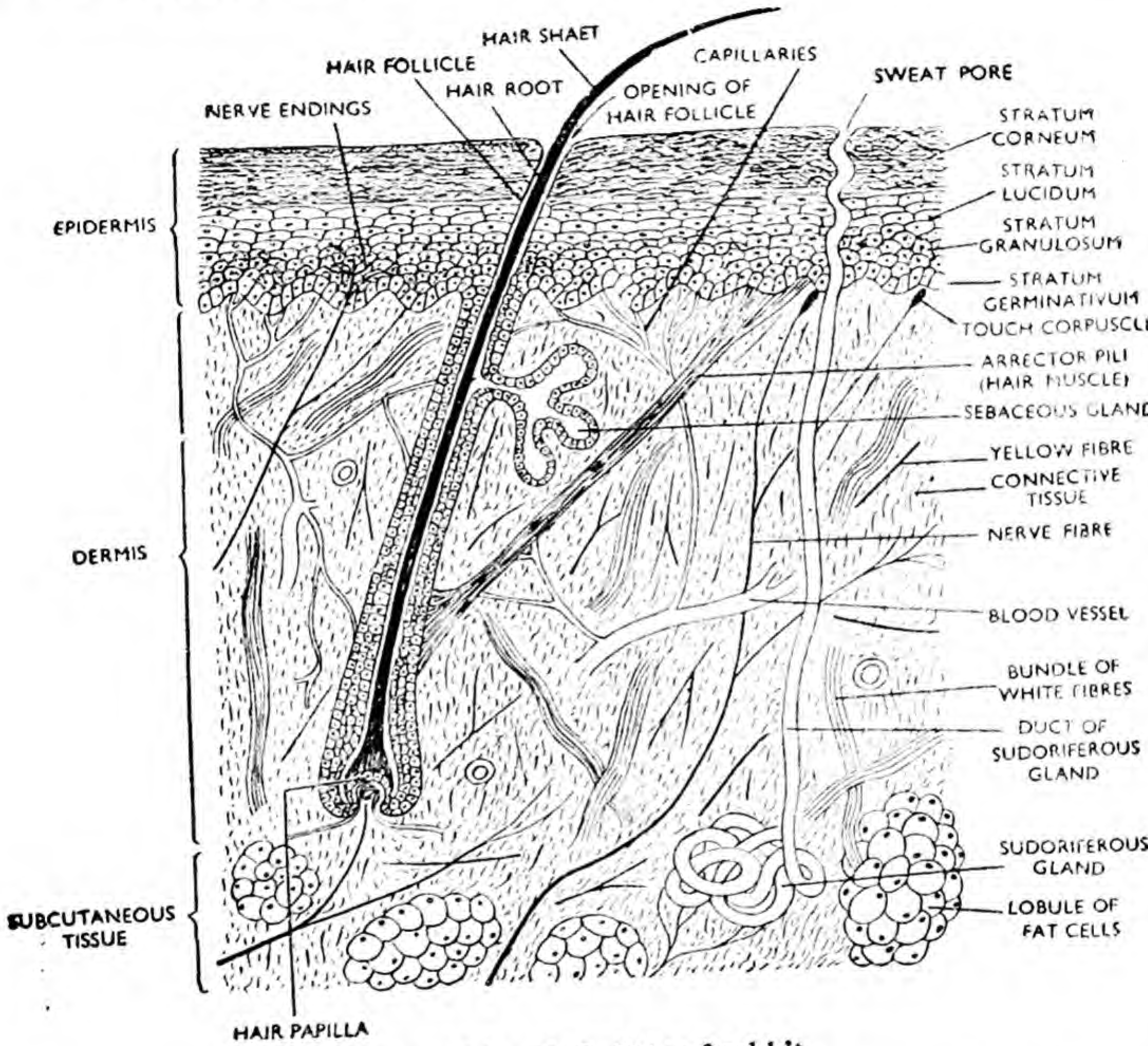


Fig. 16.1. V. S. Skin of rabbit

Beneath the dermis lies a layer of loose connective tissue with lobules **of fat** or adipose tissue in its interstices. This layer is called the **subcutaneous tissue**. In palms and soles the fibres of this tissue are tightly interwoven with those of the dermis. The skin is, therefore, more firmly attached in these regions.

II. Derivatives of the Skin

1. Hair. The hair develop from the epidermis. The Malpighian layer of the epidermis sinks into the dermis to form long tubular pits called **the hair-follicles.** The base of the follicle projects upwards into the

follicle as a small papilla, the **hair-papilla.** The hair papilla is nourished and innervated by a few blood-capillaries and nerves of the **dermis.** The cells of the papilla, being ordinary Malpighian cells and provided with food, produce new cells which gradually become flat and horny like the cells of the outer layer of epidermis. The piling up of the horny cells in due course of time results in the formation of a hair. The hair has two parts : **root** within the follicle and the **shaft** projecting out of the skin. The hair are normally slanting but they can be made to stand on end by **arrector pili muscle** which consists of a bundle of smooth fibres. This often happens when the animal is frightened or experiences excessive cold and is brought about by the hormone adrenalin. Colour of the hair is due to pigments in their cells. The hair prevent loss of heat from the body. Vibrissae act as touch receptors. Eyelashes and the hair in and around the nares keep out the coarse air-borne particles of dust. The hair also provide colour to the body.

2. Glands. The glands developed in the skin include the sweat or sudoriferous glands, oil or sebaceous glands, milk or mammary glands, Meibomian glands and ceruminous glands. All these glands, though situated in the dermis, are epidermal in origin.

(*a*) **A sweat gland** is a much-convoluted tube situated deep in the dermis. It is formed by invagination of the Malpighian layer of the epidermis. It opens on the surface of the skin by a long duct. Its opening is called the **sweat pore.** The gland is surrounded by a network of blood capillaries from which it separates the sweat or perspiration and discharges it to the exterior. The sweat consists of water with some urea, inorganic salts (chiefly sodium chloride) and carbon dioxide. The sweat glands bring about the excretion of waste materials and cooling of skin is caused by the evaporation of the sweat.

(*b*) An **oil gland** consists of small saccules communicating with a common duct that opens into the hair-follicle. It lies in the triangle formed by the hair-follicle, its arrector pili muscle and epidermis. It secretes an oily material, the **sebum,** which lubricates the hair and the skin to keep them soft and flexible and also prevents drying of skin.

(*c*) The **milk glands** secrete milk They are modified sudoriferous glands. They are aggregated at certain places and open on the teats or nipples by several small apertures. The milk glands become functional just after the birth of the young one.

(*d*) The **Meibomian glands** are modified sebaceous glands. They open into the follicles of the eyelashes.

(*e*) The **ceruminous glands** are modified sweat glands. They occur in the external auditory canal. They secrete a fatty substance, the earwax or **cerumen,** which protects and lubricates the tympanic membrane.

3. Claws. The claws are hard, curved, sharply-pointed structures covering the tips of the digits. They are composed of keratin and are produced by the Malpighian layer of epidermis. The claws are used by rabbit in digging burrows and as organs of offence and defence.

III. Functions of the Skin

The skin performs a variety of functions which justify its title "**the master organ**" of the body. The skin acts as :—

(1) **a protective organ.** It forms a wrapper for the internal organs to protect them from mechanical injury, entry of micro-organisms, evaporation of water and absorption of poisons.

(2) **an excretory organ.** It removes the excess of water, urea and salts from the blood through the agency of sweat glands.

(3) **a secretory organ.** It secretes oil for the lubrication of the hair, milk for nourishment of young ones, and earwax for the lubrication of ear-drum.

(4) **a sense organ.** The receptors of the skin are sensitive to touch, heat, cold, pain, chemicals and moisture.

(5) **a storage organ.** The deeper layer of the dermis stores water and fat.

(6) **a heat-regulatory organ.** The hairy covering and fat in the dermis conserve body heat. The sweat cools the skin if it gets overheated.

(7) **an absorbing organ.** Some absorption of ointments, iodine, etc. occurs through the sweat pores and openings of the hair-folli cles.

(8) **a nourishing organ.** The skin is capable of forming vitamin D in it in the presence of sun-light.

(9) **a respiratory organ.** Very slight exchange of gases may occur through the skin.

(10) **a defensive organ.** The skin produces defensive tools in the form of claws. Erection of hair presents a terrifying look to the predator. Hair give some degree of camouflage.

TEST QUESTIONS

1. Give a labelled diagram of a vertical section through the skin of rabbit.
2. Describe in detail the structure of the mammalian skin.
3. Enumerate the functions of the skin in the mammals.
4. Name and describe the cutaneous glands of rabbit.

CHAPTER **17**

Oryctolagus cuniculus

(The Rabbit)

SKELETAL SYSTEM

Hard parts of the animal body collectively form the **skeletal system or skeleton**. The skeleton is of two types : **exoskeleton** and **endoskeleton.** The exoskeleton includes the hard parts covering the body externally, *e.g.* the hair, claws, etc. These structures are epidermal in origin and are mainly dead. The endoskeleton comprises the hard parts lying inside the body, *e.g.* the **cartilages** and the **bones.** These structures are mesodermal in origin and are living.

Bone Formation. Originally the whole of the endoskeleton is cartilaginous but later, as the animal grows, it gradually becomes bony. Bones develop from three sources. Certain bones are formed from the original cartilages and are called the **cartilage** or **replacing bones**. Others arise in the dermis of the skin and sink below to get attached over the underlying cartilaginous skeleton. These are called the **membrane** or **investing bones.** Some bones develop at the joints of the skeleton by ossification in the tendons to give extra strength. They are termed the **sesamoid bones.**

Structure of the Mammalian Bone. Bone consists of bone-cells or **osteocytes** scattered in a hard intercellular substance or **matrix.** The matrix is formed of a protein called **ossein**. It contains a strengthening framework of white or collagen fibres. The fibres are, however, difficult to detect as they are heavily impregnated with inorganic salts, chiefly calcium phosphate and calcium carbonate. Bone, thus, combines mineral matter with animal matter. Examination of a dried bone reveals the mineral matter while that of the decalcified bone shows the animal matter. The following description is of a decalcified bone.

Bone is covered externally by a tough sheath of white fibrous connective tissue. It is known as the **periosteum.** The muscles are attached to this sheath. It contains blood-vessels which pass into the bone for providing nourishment. It also contains special bone-forming cells, the **osteoblasts,** which produce new bone material. In a young growing bone, osteoblasts are arranged in a regular epithelium near the inner limit of the periosteum. Periosteum is, thus, a multipurpose sheath. It is responsible for the protection, muscle attachment, nourishment, growth and repair of the bone.

Small bones are solid. Long bones like the femur, have a cavity in them. This is called the **marrow cavity.** It is lined by a layer of

connective tissue, the **endosteum**. The endosteum also contains the bone-forming cells which produce new bone material. The long bones, thus, grow in thickness from two sides.

The marrow cavity is filled with a fatty tissue, the **bone marrow**. The marrow is of two types: red and yellow. The red marrow is more highly vascular and produces the red corpuscles and granular white corpuscles. The yellow marrow produces corpuscles in emergency, *i.e.* in case of a greater loss of blood.

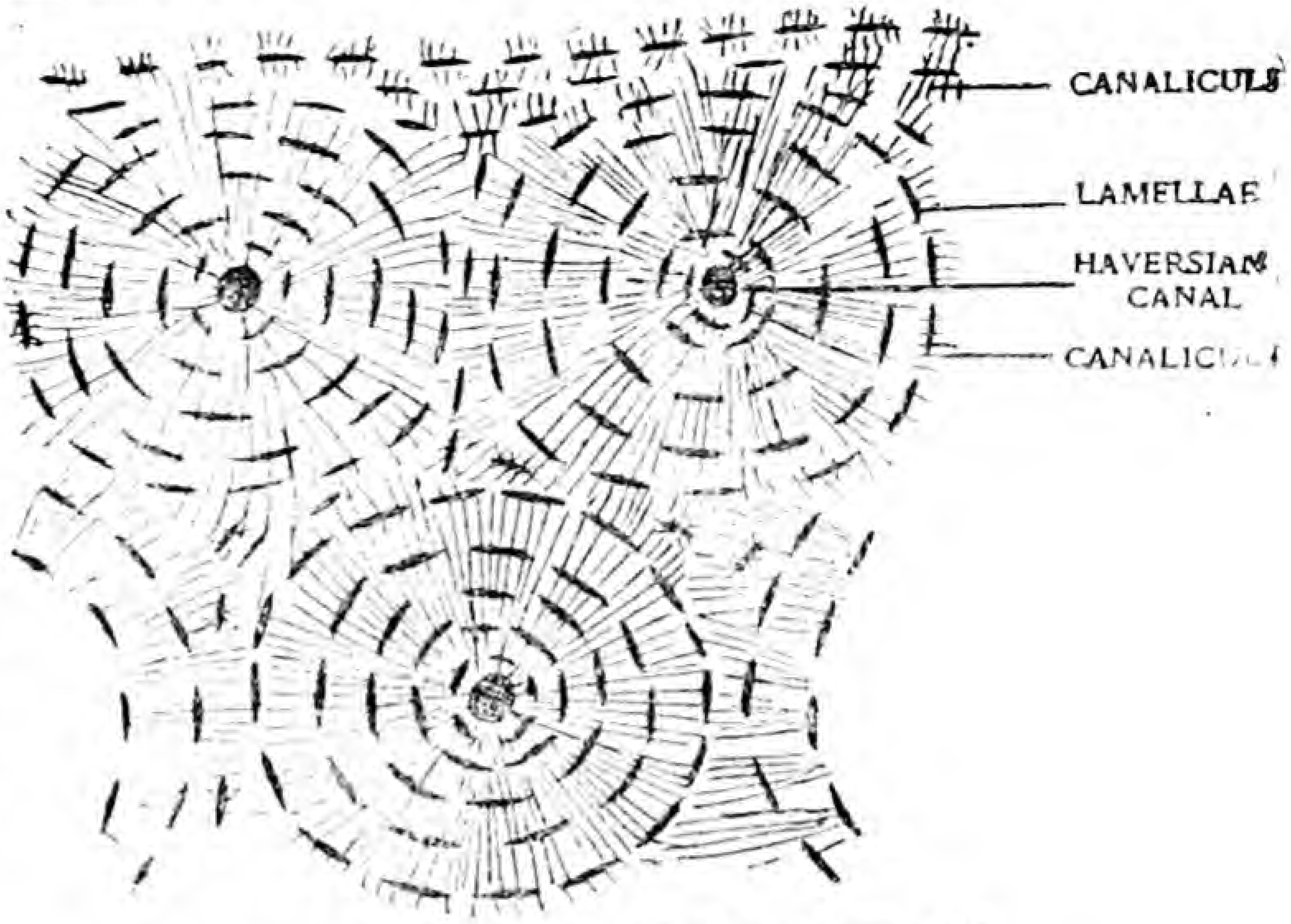


Fig. 17.1. A part of the transverse section of mammalian bone

Bone contains several narrow canals, the **Haversian canals**. The canals run more or less parallel to the long axis of the bone and join each other here and there. Each canal houses blood-vessels, nerves and bone-cells packed in areolar tissue. The blood-vessels of the Haversian canals are connected with those of the periosteum and bone marrow. Matrix occurs as layers of **lamellae** which are largely arranged in concentric rings round the Haversian canals. A few lamellae are, however, concentric round the marrow cavity. They occur just inside the periosteum as well as just outside the endosteum. Between the lamellae are found small spaces, the **lacunae**. Each lacuna contains a bone-cell or osteocyte. The bone-cells give off from their periphery several branching processes which join similar processes from the neighbouring cells. The processes lie in fine tubular spaces, the **canaliculi**, which extend outwards from the lacunae. A Haversian canal together with its lamellae, lacunae and canaliculi forms the **Haversian system**. A few **interstitial lamellae** fill up the spaces between the Haversian systems.

Functions of the Endoskeleton. The endoskeleton plays an important role in the life of the vertebrates. It forms a rigid framework to give support and characteristic shape to the body. It protects the more vital organs like the brain, spinal cord, sense organs, heart and lungs. It furnishes a hard surface for the attachment of muscles to make them effective in movements. Lastly, it produces blood-corpuscles.

Parts of the Endoskeleton. The endoskeleton (Fig. 17.2) is divisible into two main parts : the **axial skeleton** and the **appendicular skeleton.** The axial skeleton lies along the principal axis of the body, *i.e.* along the line connecting the snout with the tail. It consists of the **skull** present

in the head, **vertebral column** extending along the mid-dorsal line of the neck, trunk and tail, the **sternum** situated in the mid-ventral

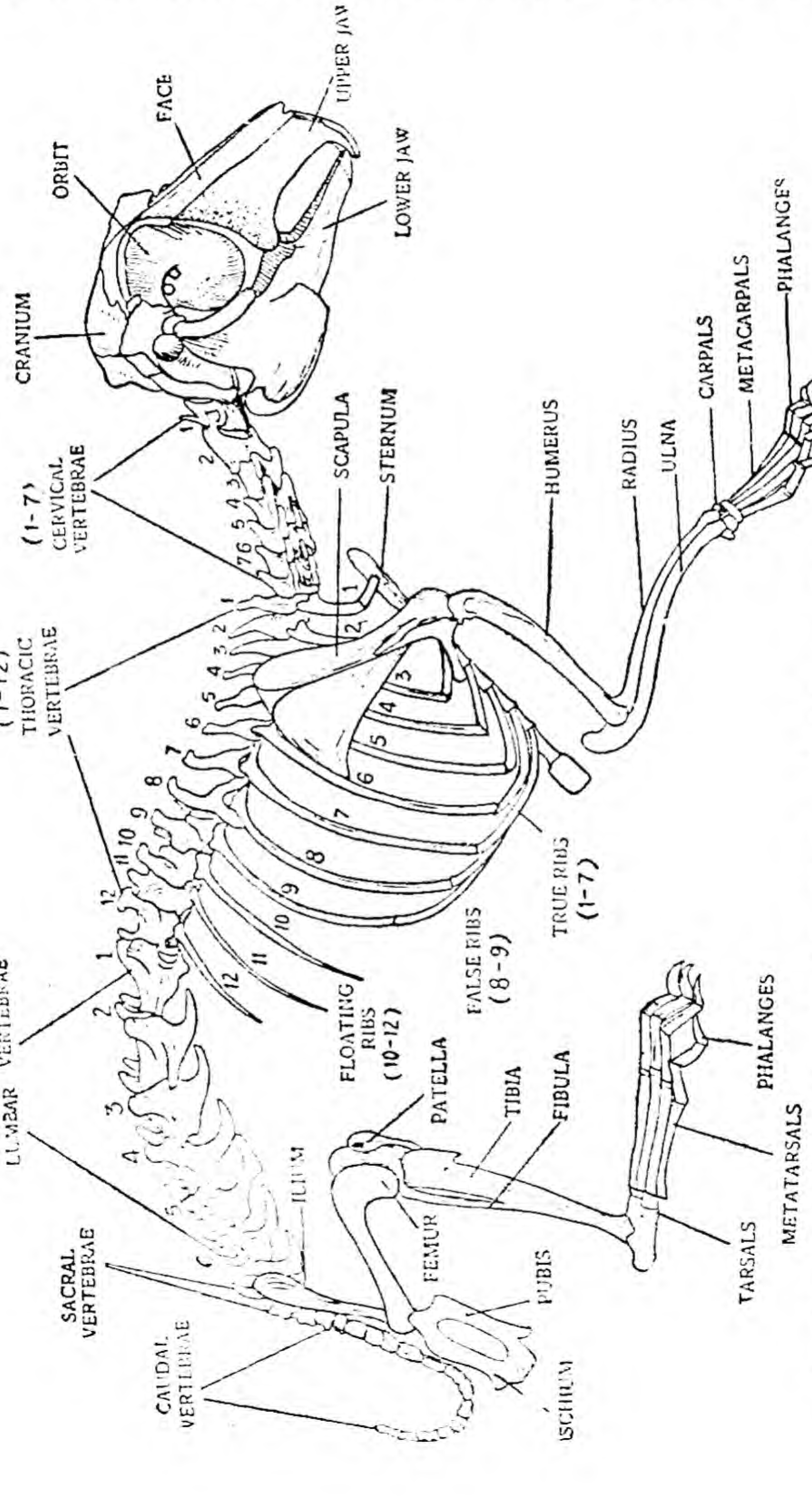


Fig. 17.2. Articulated skeleton of rabbit—side view, Limb bones and girdles of the left side have not been shown

line of the thorax and the **ribs** on the sides of the thorax. The appendicular skeleton is situated along the two secondary axes which cross the principal axis almost at right angles, one just behind the neck and the other just in front of the tail. It comprises the girdles, **pectoral** and **pelvic**, and the **limb bones**.

I. Skull

The skull (Figs. 17.3—17.5) forms the skeleton of the head, protects the brain and sense organs (nose, eyes and ears) and bounds the mouth as jaws. The skull is almost entirely bony. A large part of it is first laid down as a framework of cartilage. In this condition it is called the **chondrocranium**. The chondrocranium later gets ossified to form the cartilage bones. At the same time a number of membrane bones arise superficially and get fused with the cartilage bones.

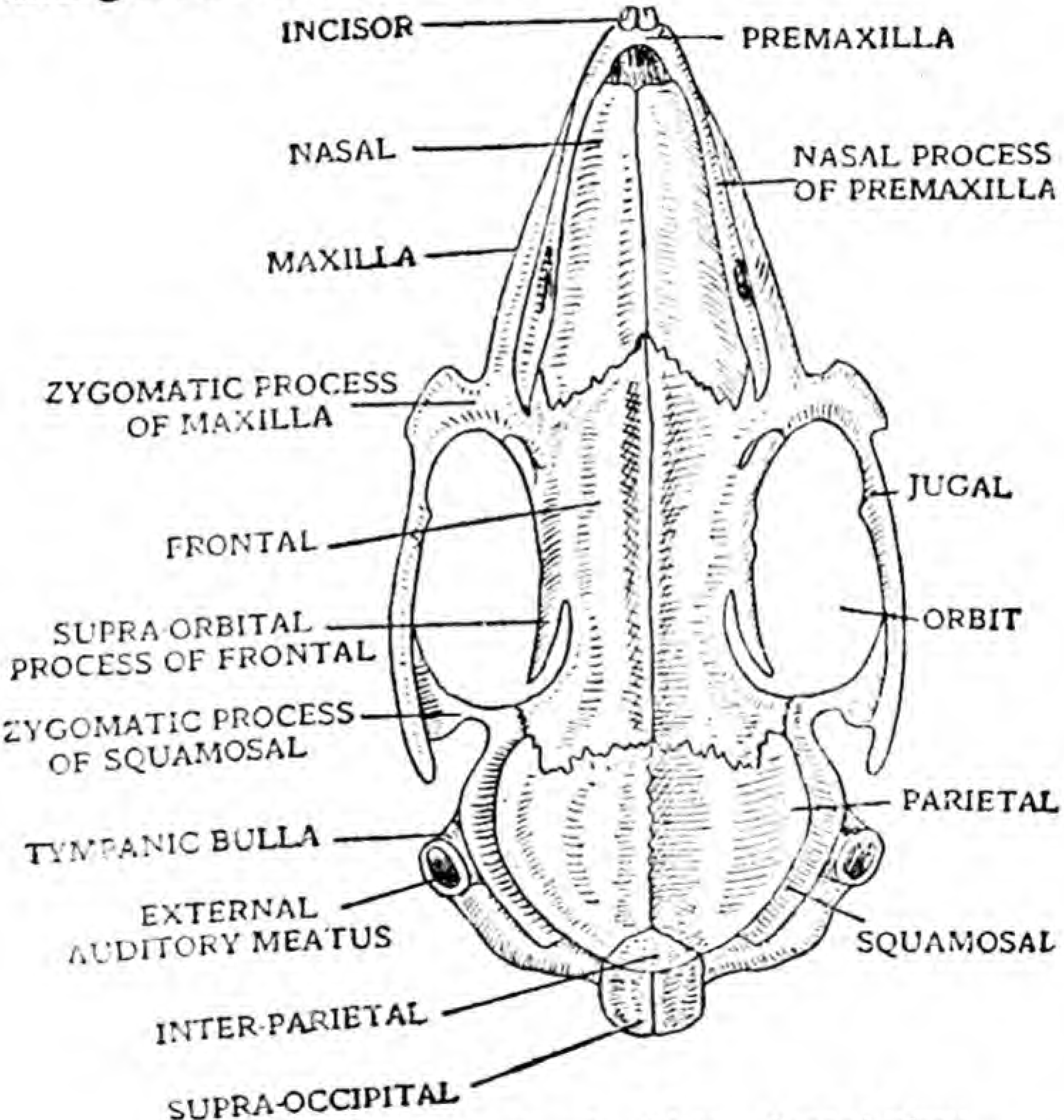


Fig. 17.3. The skull of rabbit—dorsal view

For convenience of description the skull may be divided into the **cranium or brain-case**; the **sense capsules**, namely, **olfactory**, **optic** and **auditory**; the jaws, upper and lower; and the **hyoid apparatus**.

1. Cranium. The cranium or the brain-case forms the posterior hollow part of the skull and lodges the brain. It is composed of fifteen bones arranged in three segments, namely, the posterior **occipital segment**, the middle **parietal segment** and the anterior **frontal segment**.

The **occipital segment** is the smallest of the three segments of the cranium. It has a wide aperture, the **foramen magnum**, on the posterior side. Through this aperture the brain and the spinal cord merge into

one another. This segment consists of four bones : a **supra-occipital, two exoccipitals** and a **basioccipital**. All these are cartilage bones. The supra-occipital lies above the foramen magnum and forms the roof of the hinder part of the **cranial cavity**. It bears above a prominent shield-shaped projection. The exoccipitals are a pair of vertical bones situated on the sides of the foramen magnum. Each is produced externally into a downwardly-directed conical process, the **paroccipital process**. The basioccipital lies below the foramen magnum and forms the floor of the hinder part of the cranial cavity. The occipital segment articulates behind with the **atlas vertebra** by a pair of elevations, **the occipital condyles**, which are formed mainly by the exoccipitals and partly by basioccipital.

The **parietal segment** is larger than the occipital segment. It is joined with the occipital segment dorsally and ventrally but is separated from it laterally due to the presence of the **auditory capsules** and the **squamosal bones**. The parietal segment is made up of six bones : two **parietals**, an **inter-parietal**, two **alisphenoids** and a **basisphenoid**. Of these, the parietals and the inter-parietal are membrane bones while the rest are cartilage bones. The parietals are broad, almost squarish bones forming the roof of the middle part of the cranial cavity. They meet together along the mid-dorsal line by a suture. The inter-parietal is a small median triangular bone intercalated between the parietals and the supra-occipital. The alisphenoids are semivertical, irregular bones forming the ventro-lateral wall of the cranium in the parietal segment. Each is produced ventrally into two thin plates which meet anteriorly to form the **pterygoid process**. The basisphenoid is a median triangular bone united behind with the basioccipital by a cartilage. It forms the floor of the middle part of the cranial cavity. It has a small aperture, the **pituitary foramen**, in its middle.

The **frontal segment** is the largest of the cranial segments. It is formed of five bones : two **frontals**, two **orbito-sphenoids** and **a pre-sphenoid**. Of these, the frontals alone are the membrane bones, the rest being all cartilage bones. The frontals are large, roughly rectangular bones forming the roof and part of the sides of the anterior part of the cranial cavity. They meet together along the mid-dorsal line by a suture. The outer end of each frontal bone is produced into a crescentic process, the **supra-orbital ridge**, which overhangs the orbit. The orbito-sphenoids are almost vertical bones completing the sides of the cranial cavity. They form the upper and hinder borders of a large aperture, the **optic foramen**, which connects the two orbits with each other and also with the cranial cavity. The presphenoid is a median, laterally compressed bone forming the lower and front borders of the optic foramen. It is attached behind with the basisphenoid by a cartilage.

The cranial cavity is closed anteriorly by a vertical bone, the **cribriform plate**, perforated by several apertures for the branches of the olfactory nerves. This plate is formed by the ossification of the lateral expansions from the hinder end of the **mesethmoid**. It is, thus, a cartilage bone.

2. Sense Capsules. The sense capsules lodge and protect the sense organs. There are three pairs of such capsules : the **auditory capsules** that surround the organs of hearing, the **olfactory capsules** which enclose the organs of smell, and the **optic capsules** or the orbits round the organs of sight.

The **auditory capsules** are situated on the sides of the cranium wedged inbetween the occipital and parietal segments. Each capsule in the adult animal consists only of a single cartilage bone, the **periotic**. In the embryo, however, there are three small bones (the **prootic**, the **epiotic** and the **opisthotic**) which later fuse to form the periotic. The periotic has two portions : the inner **petrous** and the outer **mastoid**. The petrous portion is very dense and encloses the internal ear. It has, in its outer wall, two small apertures, the anterior **fenestra ovalis** and the posterior **fenestra rotunda**. The mastoid portion is porous and visible externally. It is produced downwards into a process, the **mastoid process**, lying just in front of the paroccipital process.

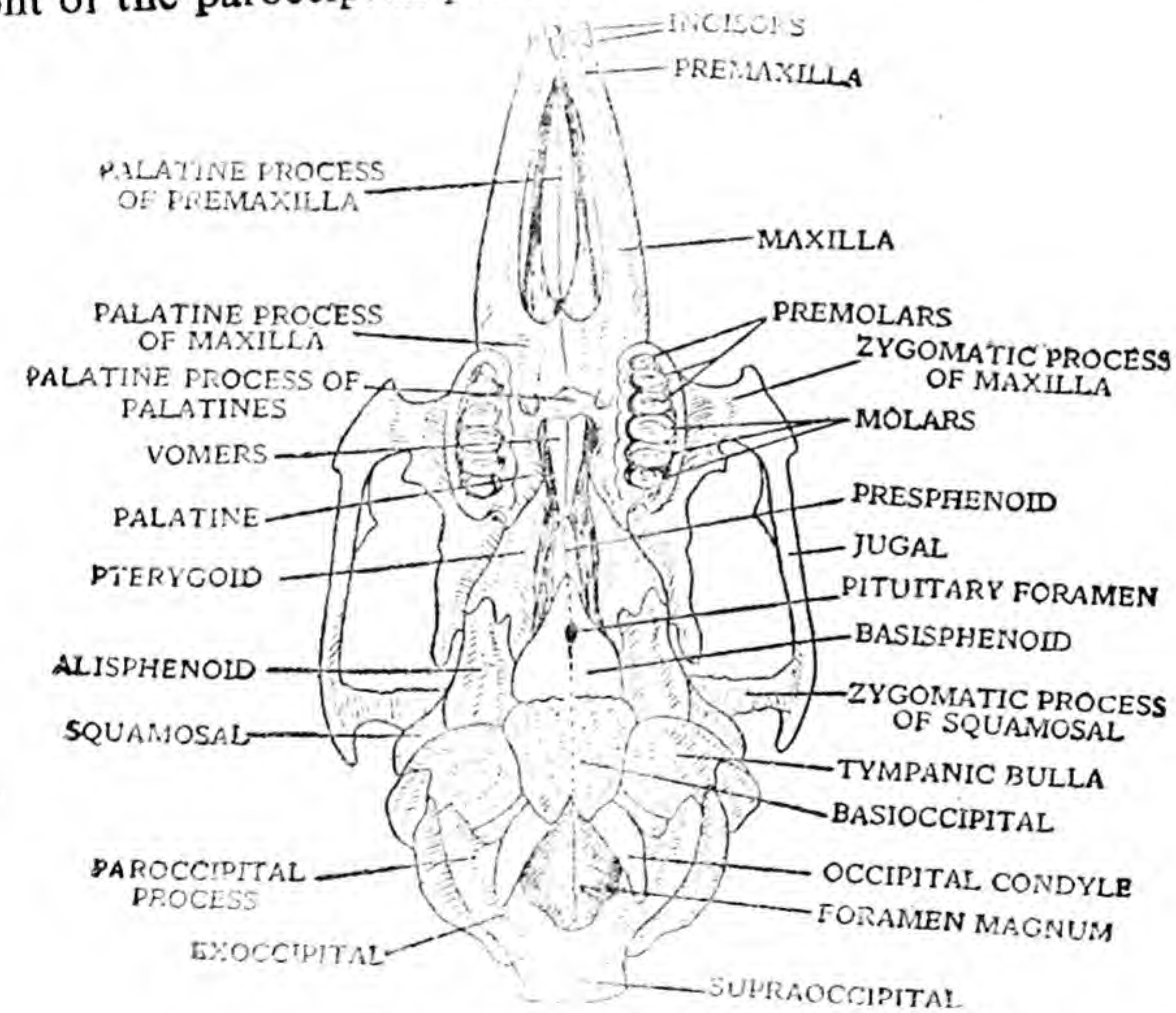


Fig. 17.4. The skull of rabbit—ventral view

A flask-like membrane bone, called the **tympanic**, lies outside each periotic. The lower swollen portion of tympanic is called the **tympanic bulla** while its upper narrow tubular part is known as the **external auditory canal**. Inside the tympanic, at the junction of the bulla and the canal, is stretched the **tympanic membrane** or the **eardrum** during life. The cavity enclosed in the bulla is the cavity of the middle ear. It communicates with the pharynx through a tube called the **Eustachian**

tube. A chain of three cartilage bones : the **malleus, incus and stapes,** pass across the cavity of the bulla.

The **olfactory capsules** are situated in front of the cranium. They are bounded dorsally by long membrane bones, the **nasals**, and laterally by the jaw-bones (premaxillae, maxillae and palatines). The two olfactory or nasal chambers are separated from each other by a median vertical partition, the **mesethmoid.** Its anterior part is cartilaginous and posterior bony. They are respectively called the **nasal septum** and the **ethmoid bone.** The latter joins the cribriform plate described earlier. The mesethmoid fits below into a groove on the upper side of a slender membrane bone formed by the fusion of a pair of **vomers.**

Three pairs of much folded bones project into the olfactory chambers from the ethmoid, nasals and maxillae. These are respectively called the **ethmo-turbinals,** the **naso-turbinals** and the **maxillo-turbinals.** The turbinals increase the internal surface of the capsules.

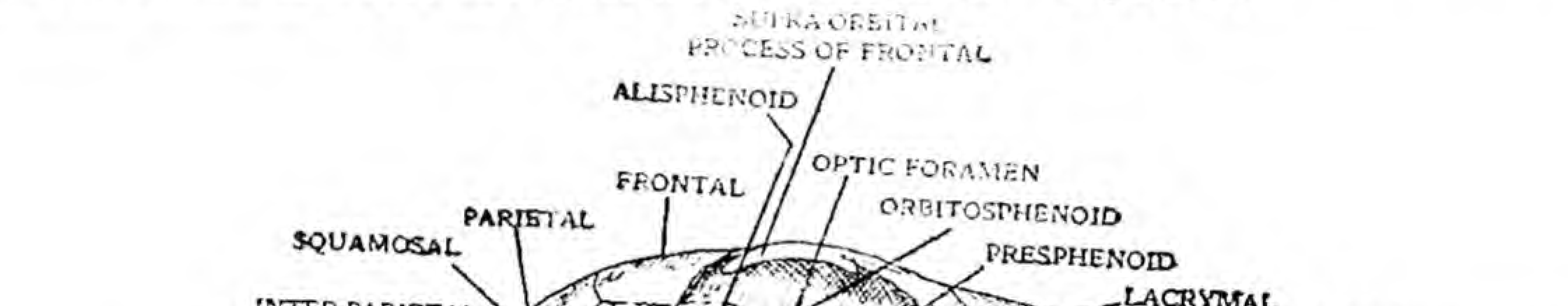


Fig. 17.5. The skull of rabbit—lateral view

The **optic capsules** are two large excavations on the sides of frontal segment of cranium. The two are separated from each other by a thin vertical partition, the **interorbital septum,** bearing a large apertnre, the **optic foramen,** for the optic nerves. The interorbital septum is made up of the orbitosphenoid above and behind the optic foramen and of presphenoid below and in front. The orbit is bounded dorsally by the frontal ; anteriorly by the maxilla and a small membrane bone, the **lacrymal** ; posteriorly by the squamosal and alisphenoid ; and externally by the **zygomatic arch.**

3. Jaws. There are two jaws, the upper and the lower.

The **upper** jaw consists of two halves or **rami** which meet together anteriorly in the middle line. Each ramus consists of **six** membrane bones : the **premaxilla, maxilla, jugal, palatine, pterygoid** and **squamosal.** The premaxilla forms the anterior part of the ramus and bears sockets for the incisor teeth. It gives off a **nasal** process on the dorsal and a **palatine process** on the ventral side. The

nasal process runs backwards between the nasal and maxilla to meet the frontal. The palatine processes of the two sides run backwards side by side to form the anterior part of the **hard palate.** The maxilla is a large irregular bone situated behind the premaxilla. It consists of a large fenestrated body and the three processes The **alveolar process** runs backwards on the ventral side and bears the sockets for the **premolars and molars.** The **zygomatic process** arises from the outer side of the body and runs backwards to form the anterior part of the **zygomatic arch.** The **palatine process** arises from the inner side of the body and meets its fellow of the other side to form the middle part of the hard palate. The jugal is a laterally-compressed bone forming the middle part of the zygomatic arch. The palatine is a thin, nearly-vertical bone lying above and behind the alveolar process of the maxilla. From its anterior end, it sends inwards a horizontal process, the **palatine process,** which meets its fellow of the opposite side to form the hinder part of the hard palate. The pterygoid is also a vertical bone lying behind the palatine at the junction of basisphenoid and the alisphenoid. The squamosal is a large irregular bone lying on the lateral side of the cranium in front of the periotic. It gives off two processes. The **zygomatic process** runs forwards and forms the posterior part of the zygomatic arch. It bears on its underside an articular facet for the lower jaw. The **post-tympanic process** of the squamosal arises from the hind end and extends downwards behind the tympanic.

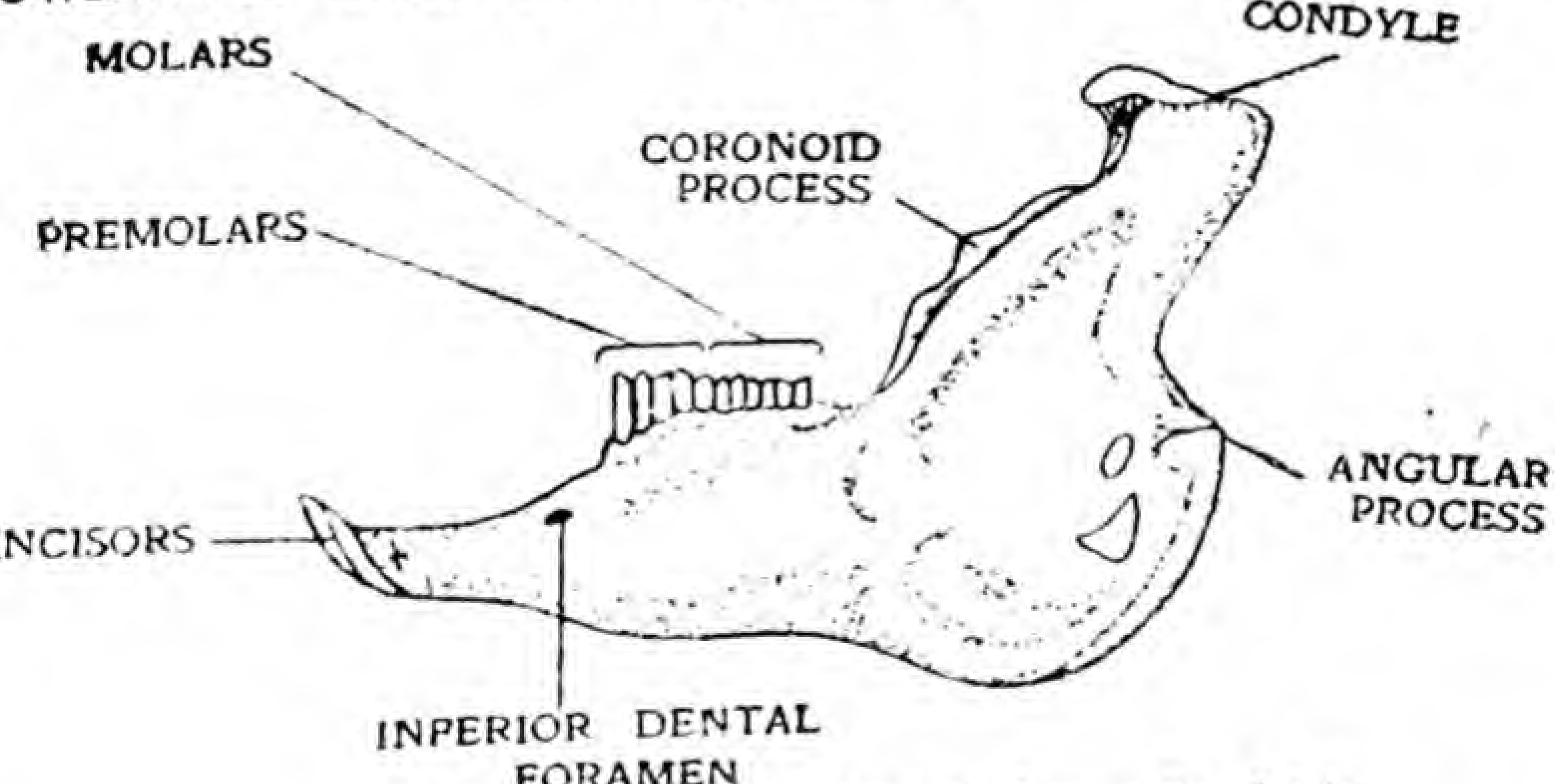


Fig. 17.6. The lower jaw of rabbit

The **lower jaw** (Fig. 17.6) consists of two halves or **rami** which are united anteriorly in the middle line. Each ramus is a single, large, triangular, vertical plate of membrane bone known as the **dentary**. The anterior half of the dentary is very stout and bears a socket for the incisor tooth in front and several sockets for the premolars and molars some distance behind. The posterior half of the dentary is much thinner and bears three processes : the **condyle,** the **coronoid** and the **angular.** The condyle is the highest point on the dentary and articulates with the zygomatic process of the squamosal. The coronoid process is the inflected ridge situated in front of the condyle and forming the outer border of the groove between the grinding teeth and the condyle. The angular process lies at the postero-ventral angle of the dentary.

4. Hyoid Apparatus. The hyoid apparatus (Fig. 17.7) lies in the floor of the hinder part of the buccal cavity between the two rami of the lower jaw. It consists of a median bony plate, the **body** or **basihyal,** which bears two pairs of backwardly-directed processes, the shorter **anterior cornua** and the longer **posterior cornua.**

II. Vertebral Column

The **vertebral column** or the backbone is a long rigid rod extending along the mid-dorsal line of the neck, trunk and tail. It consists of a row of several movably articulated bony rings, the **vertebrae,** which enclose a cavity the **neural canal,** to house the spinal cord. The vertebral column supports the body, protects the spinal cord and all the viscera are hung from it.

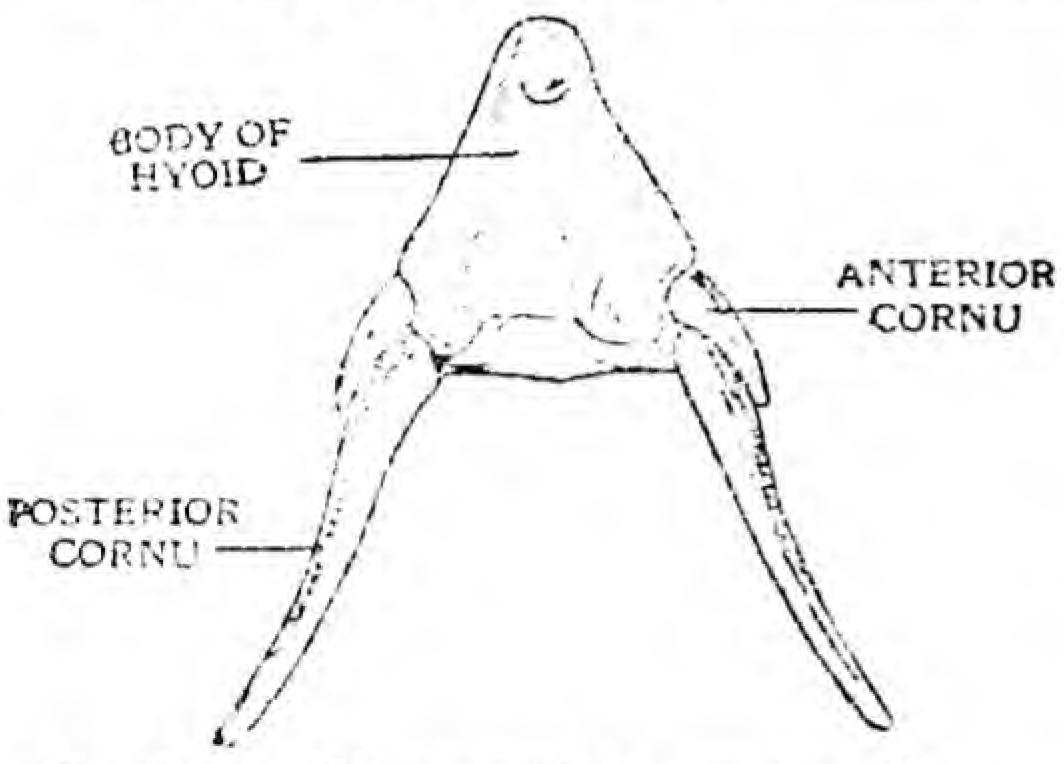


Fig. 17.7. The hyoid apparatus of rabbit

There are about forty-five vertebrae divisible into five distinct types, namely, seven **cervical vertebrae** in the neck, twelve **or** thirteen **thoracic vertebrae in** the thorax, six or seven **lumbar vertebrae** in the abdomen, three or four **sacral vertebrae** in the hip region and about sixteen **caudal vertebrae** in the tail (Fig.17.2). All the vertebrae have the same basic structure though many have a few individual characteristics of their own.

Basic Structure of a Vertebra. A vertebra, as mentioned earlier, is a bony ring enclosing the neural canal. The ventral part of the ring, *i.e.* the floor of the neural canal, is greatly thickened and is called the **centrum** or the **body** (Fig. 17.10). The remaining part of the ring forming the sides and roof of the neural canal, is much thinner and is called the **neural arch.** The centrum is flat both anteriorly and posteriorly and is called **acoelous.** It bears in front and behind thin bony discs, the **epiphyses,** which develop from independent centres of ossification but fuse with the centrum later on. Between the centra of the adjacent vertebrae are elastic pads of fibro-cartilage, the **intervertebral discs,** to make the vertebral column flexible.

The neural arch consists of a **pedicel** or **root** on either side forming the lateral wall of the neural canal and the **lamina** forming the roof of the neural canal. The anterior and posterior margins of the pedicel bear notches, the **inter-vertebral notches.** The inter-vertebral notches of the preceding and succeeding vertebrae together form rounded apertures, **inter-vertebral foramina,** for the exit of the spinal nerves. The neural arch bears dorsally a median process, the **neural spine,** and laterally a pair of projections, the **transverse processes.** These three structures provide surface for the attachment of spinal muscles and ligaments. The neural arch bears anteriorly and posteriorly short, paired processes for articulation with the adjacent vertebrae. These are called the

zygapophyses or the articular processes. The anterior articular processes or the **prezygapophyses** face upwards and are overlapped by the posterior articular processes or the **postzygapophyses**, which face downwards. The zygapophyses keep the vertebrae in position by limiting their movements on each other.

1. Cervical Vertebrae. The cervical vertebrae are, as a group, characterised by thin centra ; short neural spines ; fusion of the reduced cervical ribs with the centra and the transverse processes ; and the presence of paired apertures, the **vertebrarterial foramina**, between the neural arch, transverse processes and the ribs. The vertebrarterial foramina of all the cervical vertebrae together form a longitudinal passage, the **vertebrarterial canal**, on either side to lodge the vertebral artery.

The first and the second cervical vertebrae are specially modified to provide free movement to skull. They are called the **atlas** and the **axis** respectively. The next four cervical vertebrae (from the third to the sixth) are all alike and are described as the **typical cervicals**. The seventh is again slightly modified to afford articulation to the first pair of thoracic ribs.

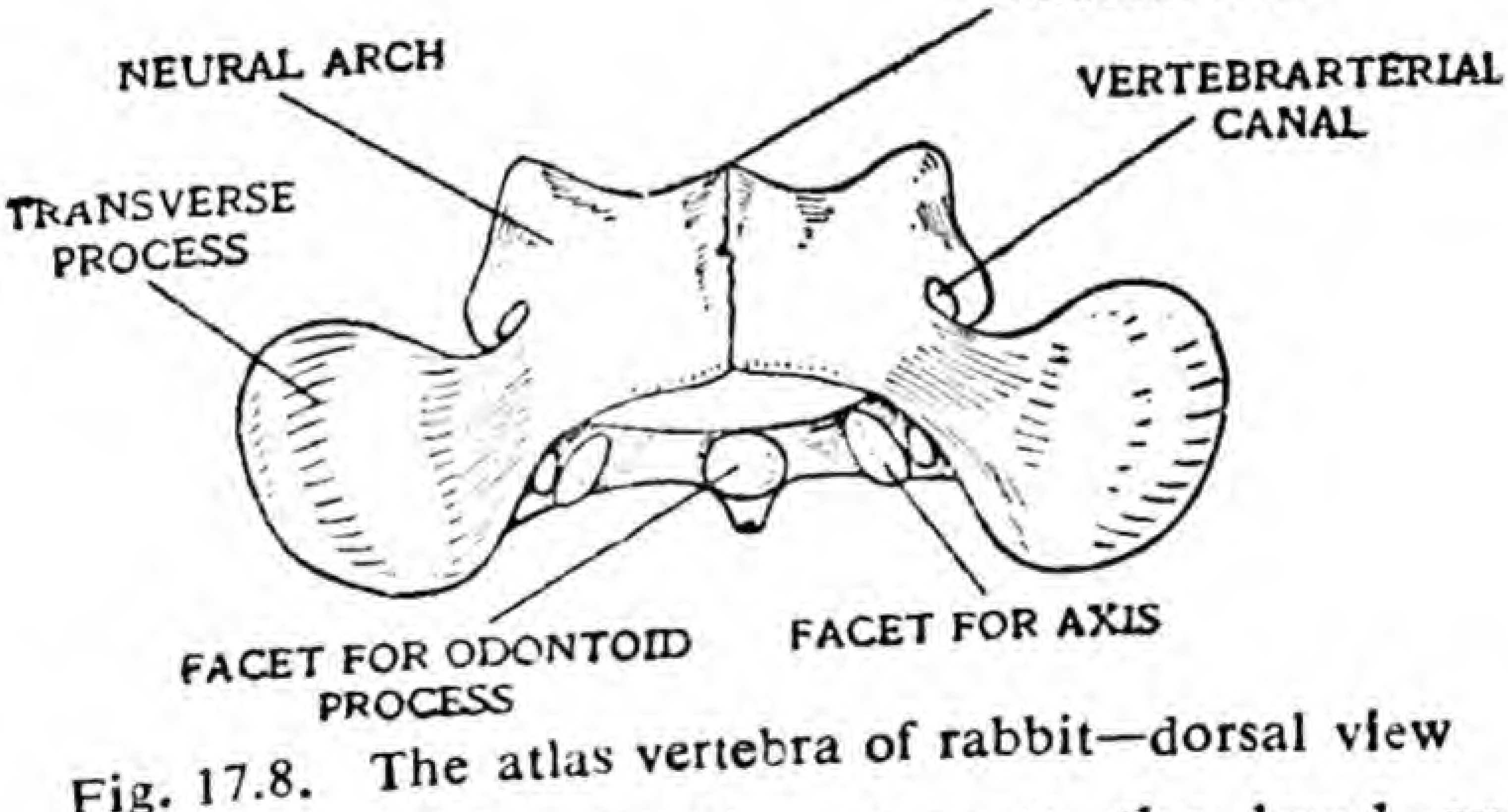


Fig. 17.8. The atlas vertebra of rabbit—dorsal view

The **atlas vertebra** (Fig. 17.8) supports the head and has been named after the mythical giant who was believed to support the earth on the shoulders. It is more ring-like as compared to others. The centrum is considerably reduced as during development the major part of the centrum separates from the atlas and gets fused with the axis. The neural canal is very wide and divided by a transverse ligament into two parts, the upper larger containing the spinal cord and the lower smaller having the **odontoid** process of the axis. The neural spine is very inconspicuous. The transverse processes are in the form of broad horizontal plates, the greater parts of which in reality are the cervical ribs. The neural arch is perforated dorsally by a pair of minute apertures through which the vertebral arteries enter the neural canal and the first pair of spinal nerves leave it. The anterior face bears two large concave facets for articulation with the occipital condyles of the skull. This articulation provides the skull only up and down or nodding movement on the atlas. The posterior face has three facets, two lateral for

articulation with the axis vertebra and one median for the odontoid process.

The **axis vertebra** (Fig. 17.9) gets its name from the fact that during the side to side or turning movements of the head, the skull and the atlas together rotate round the odontoid process, which, thus acts like an axis. Its centrum is well-developed and carries in front a peg like **odontoid process,** which is in reality the centrum of the atlas. The neural spine is in the form of a prominent vertical ridge which extends beyond the neural canal in front and behind. The transverse processes are very small. There are no prezygapophyses. The anterior face bears two large facets for articulation with the posterior lateral facets of the atlas.

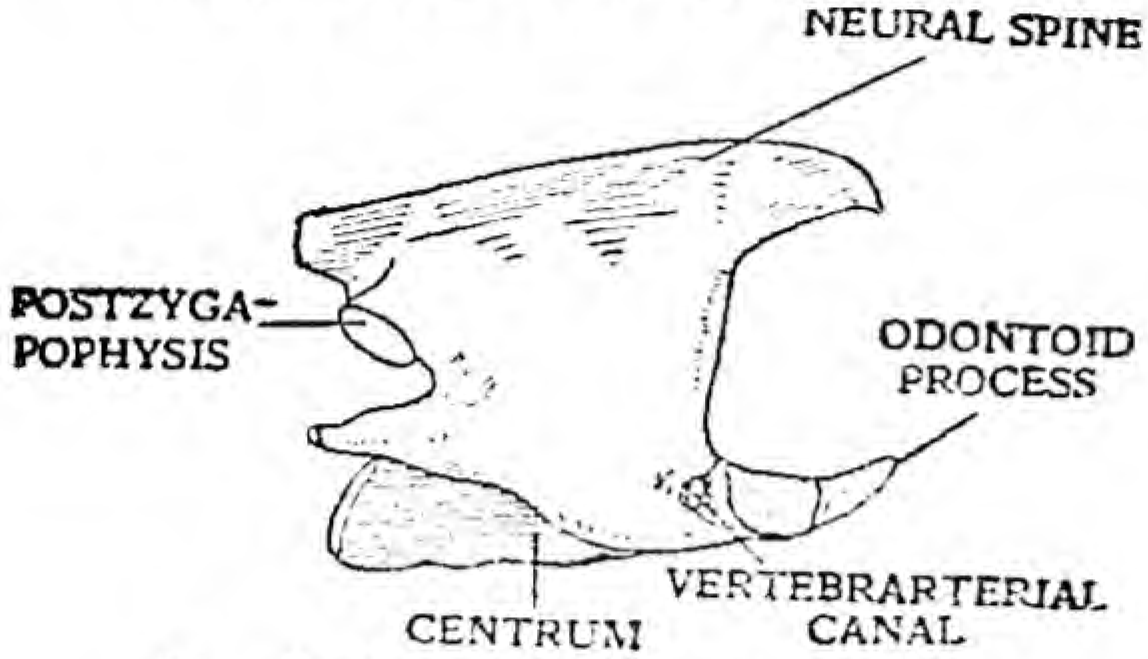


Fig. 17.9. The axis vertebra of rabbit—lateral view

The **typical cervical vertebrae** have double transverse processes (**Fig. 17.10).**

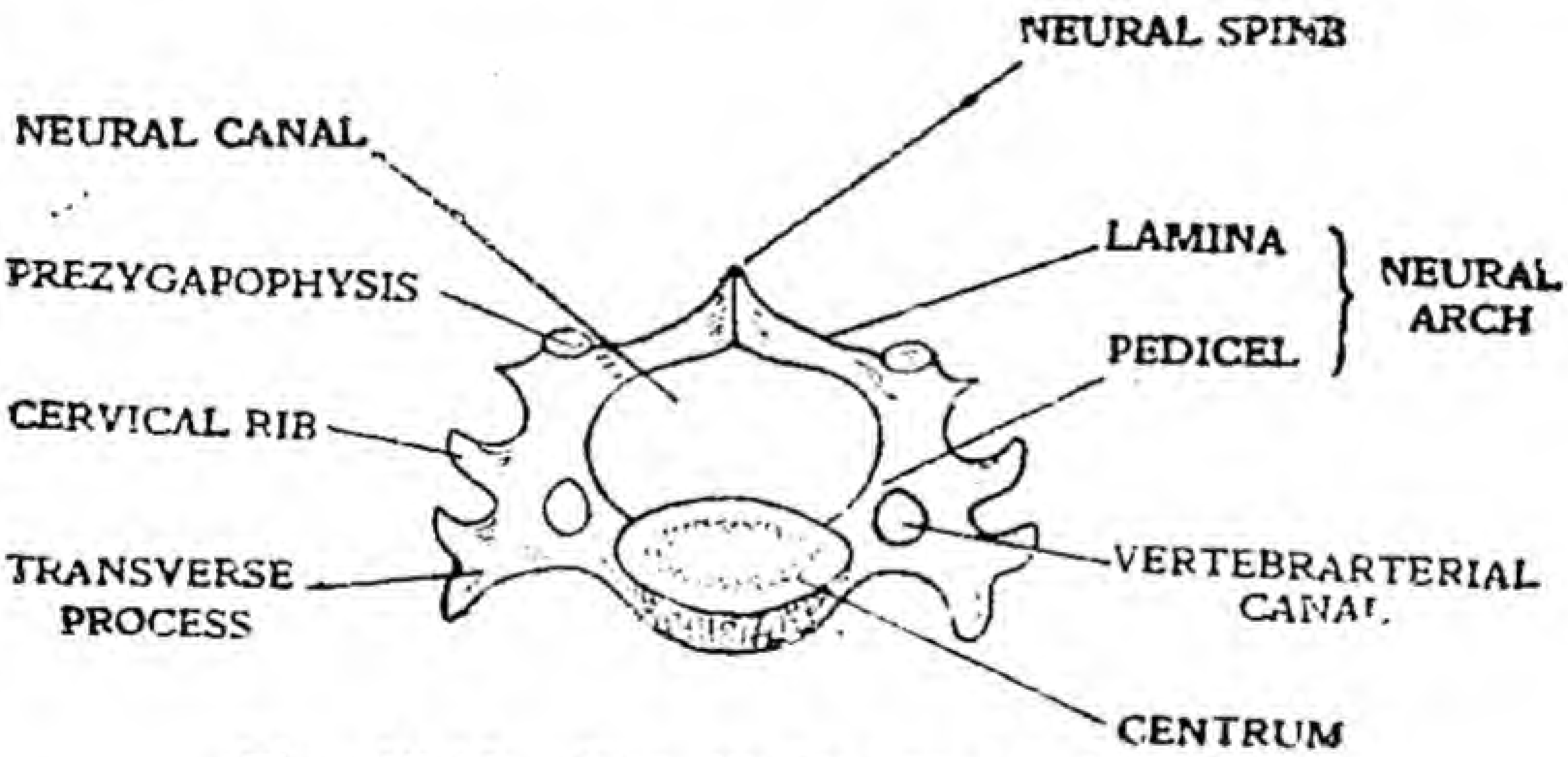


Fig. 17.10. The typical cervical vertebra of rabbit—anterior view

The **seventh cervical vertebra** is modified. Its neural spine is longer than that of the other cervicals. The centrum bears on its posterior face a pair of half facets where the first pair of thoracic ribs partly articulate. The transverse processes are not double.

2. **Thoracic Vertebrae.** The thoracic vertebrae are modified for providing articulation to the ribs. In the anterior nine thoracic vertebrae (Fig. 17.11), the centrum bears on its anterior and posterior faces a pair of half facets which together with similar half facets on the preceding and succeeding centra form the **capitular facets** for the articulation of the capitula of the ribs. The transverse processes are short and horizontal, each bearing on its underside an articular surface, the **tubercular facet,** for the articulation of the tuberculum of the rib. The neural spines are long, slender and backwardly directed. The neural arches bear notches below the zygapophyses.

In the posterior three or four thoracic vertebrae, the centrum bears capitular facets only on its anterior face. These facets receive whole of

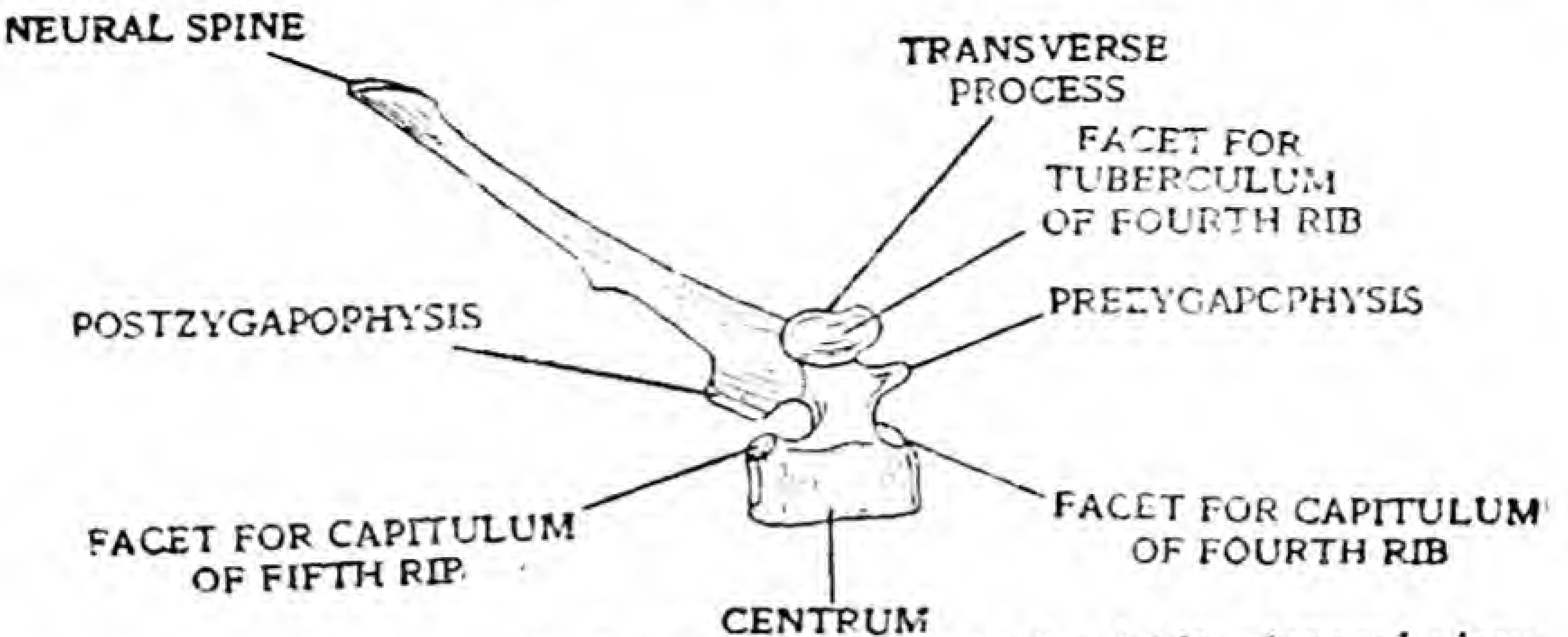


Fig. 17.11. The fourth thoracic vertebra of rabbit—lateral view

the ribs because they are complete facets. The transverse processes lack
tubercular facets as the ribs are not forked in this region. The neural
spines are short. That of the tenth vertebra projects upwards and those
of the eleventh and twelfth face forwards. Additional processes, called
the **metapophyses**, occur above the prezygapophyses. The metapophyses
may occur in the ninth vertebra also.

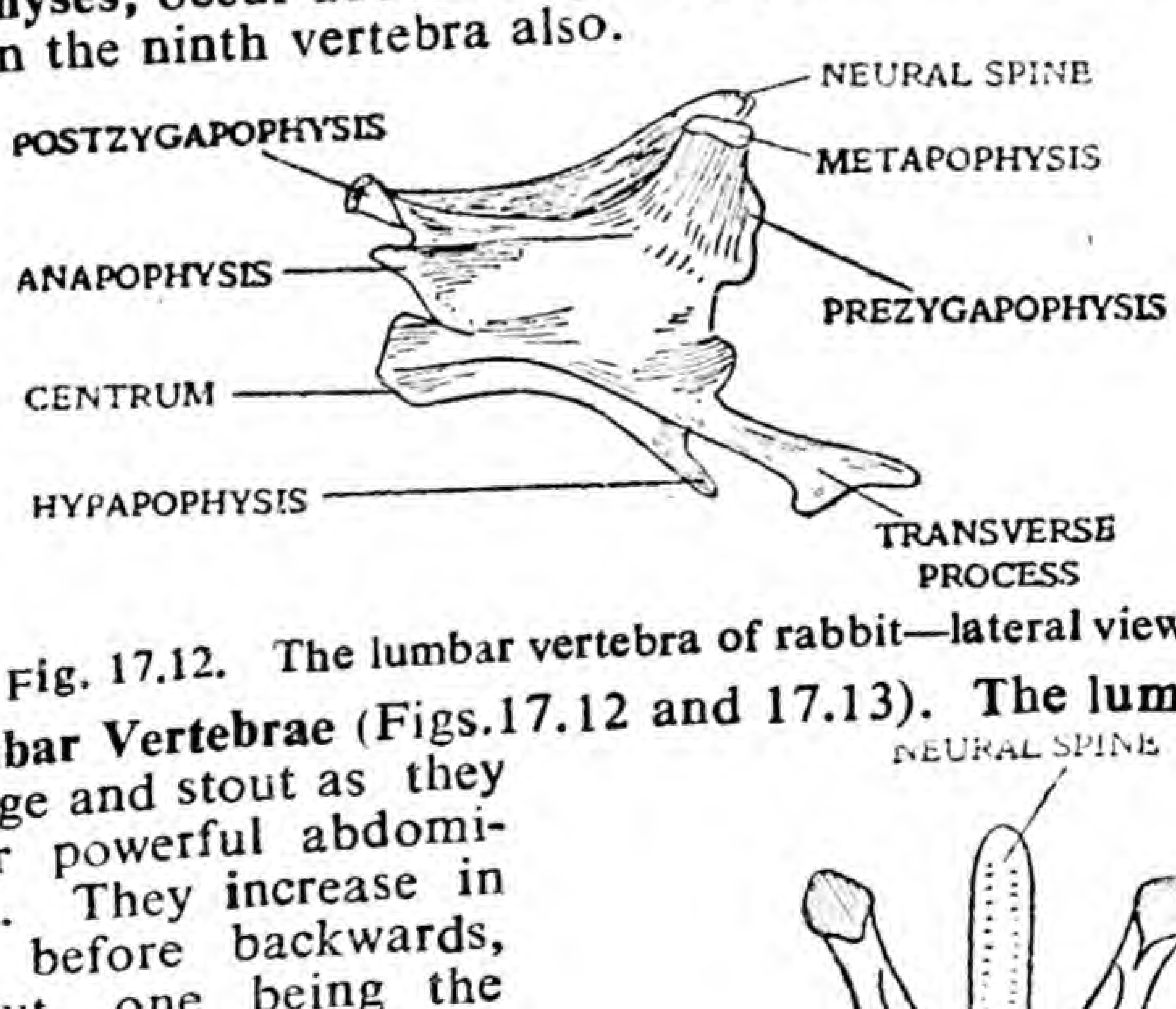


Fig. 17.12. The lumbar vertebra of rabbit—lateral view

3. **Lumbar Vertebrae** (Figs.17.12 and 17.13). The lumbar vertebrae are very large and stout as they have to bear powerful abdominal muscles. They increase in size from before backwards, the last but one being the largest. Their centrum is very strong and bears in the first two or three vertebrae a midventral process, the **hypapophysis**, which projects downwards and forwards. The neural spines face forward. The transverse processes are directed forwards, downwards and outwards. They have slightly expanded tips which represent vestigial ribs

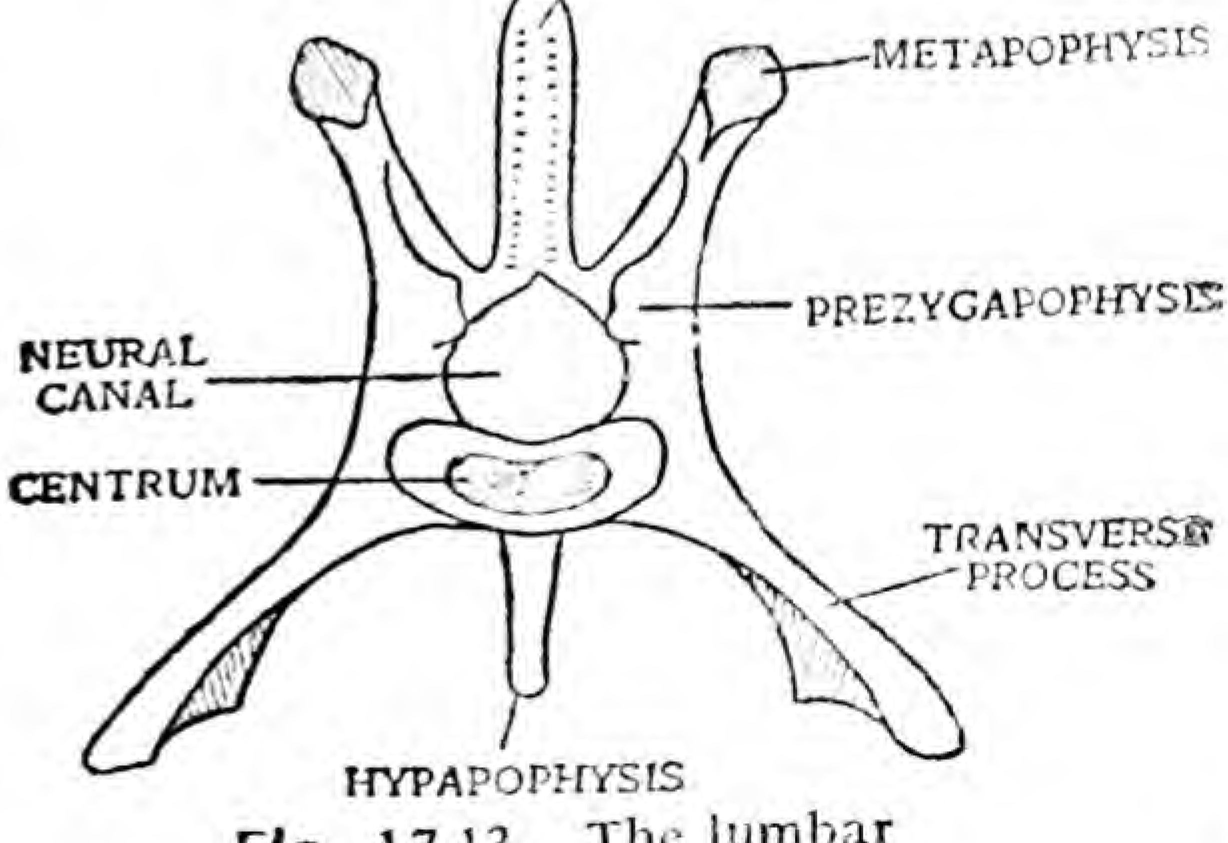


Fig. 17.13. The lumbar vertebra—anterior view

fused with them. The neural arch bears in front a pair of large upwardly directed processes, the **metapophyses**, above the prezygapophyses and behind a pair of small backwardly-directed projections, the **anapophyses**, below the postzygapophyses.

4. Sacral Vertebrae. The sacral vertebrae are fused to form a single composite structure, the **sacrum.** for giving rigid support to the pelvic girdle (Fig. 17.14). The first sacral vertebra (Fig. 17.15) has greatly expanded transverse processes which are immovably joined to the **ilia** (the plural of ilium). The second sacral vertebra also meets the ilia. These two vertebrae are, therefore, considered as the true sacral vertebrae. The remaining sacral vertebrae are, in reality, the anterior caudal vertebrae which have fused with the true sacral vertebrae. They have no direct connection with the pelvic girdle. The first sacral vertebra, besides having large transverse processes, also possesses a broad centrum, a vertical neural spine, short metapophyses and a wide neural canal. All these parts, except the transverse processes, can be made out in the remaining sacral vertebrae also.

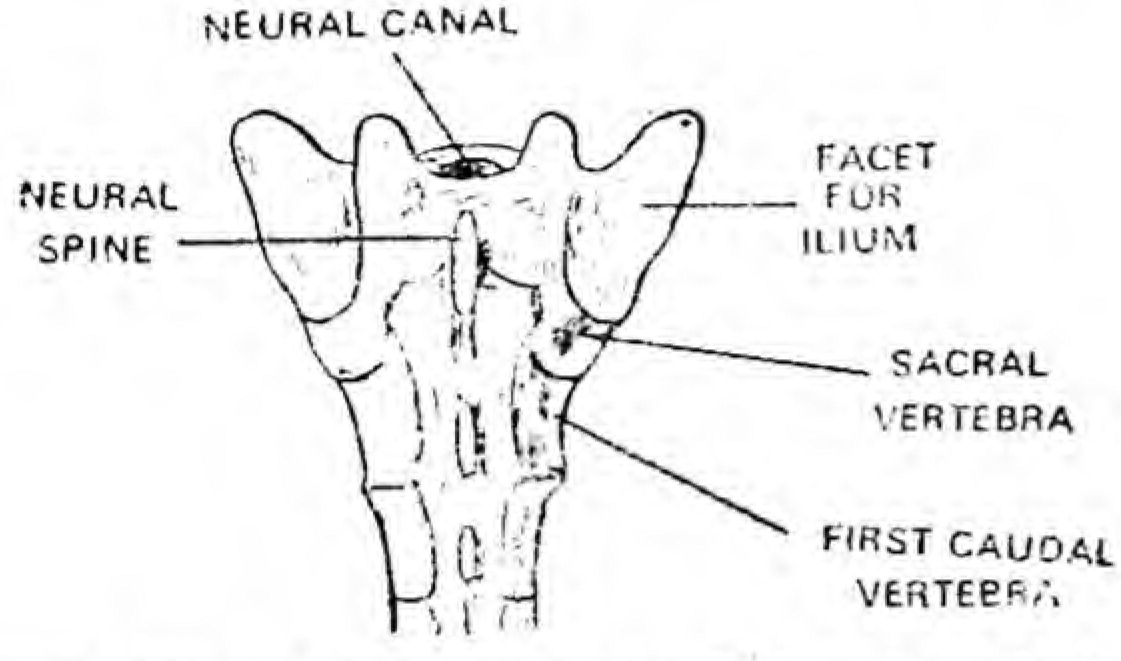
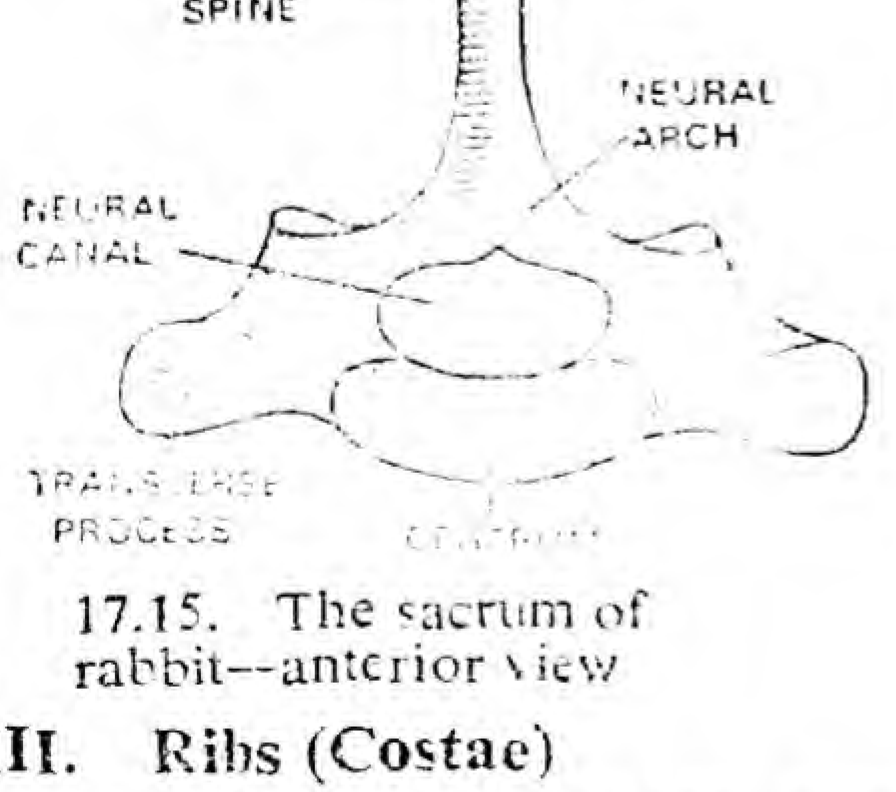


Fig. 17.14. The sacrum of rabbit—dorsal view

5. Caudal Vertebrae. The caudal vertebrae (Figs. 17.2 and 17.16) gradually decrease in size and lose their processes from before backwards. Ultimately their neural arches also disappear, leaving only the centra. Consequently near the base of the tail they are hollow cylinders and towards the tip solid rods.



17.15. The sacrum of rabbit—anterior view

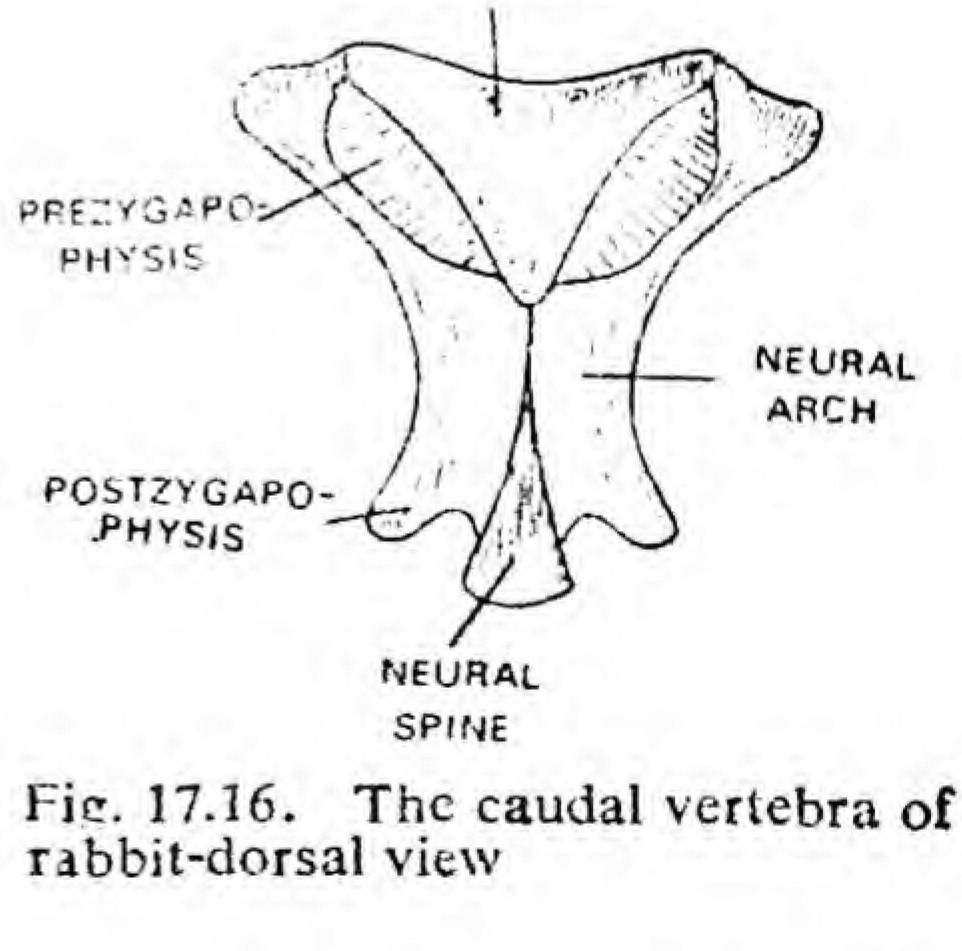


Fig. 17.16. The caudal vertebra of rabbit-dorsal view

III. Ribs (Costae)

The **ribs** are slender curved bars which movably articulate with thoracic vertebrae above and unite with the sternum below to form the

skeletal framework of the thorax. This framework protects the thoracic viscera and aids in respiration. There are twelve, sometimes thirteen,

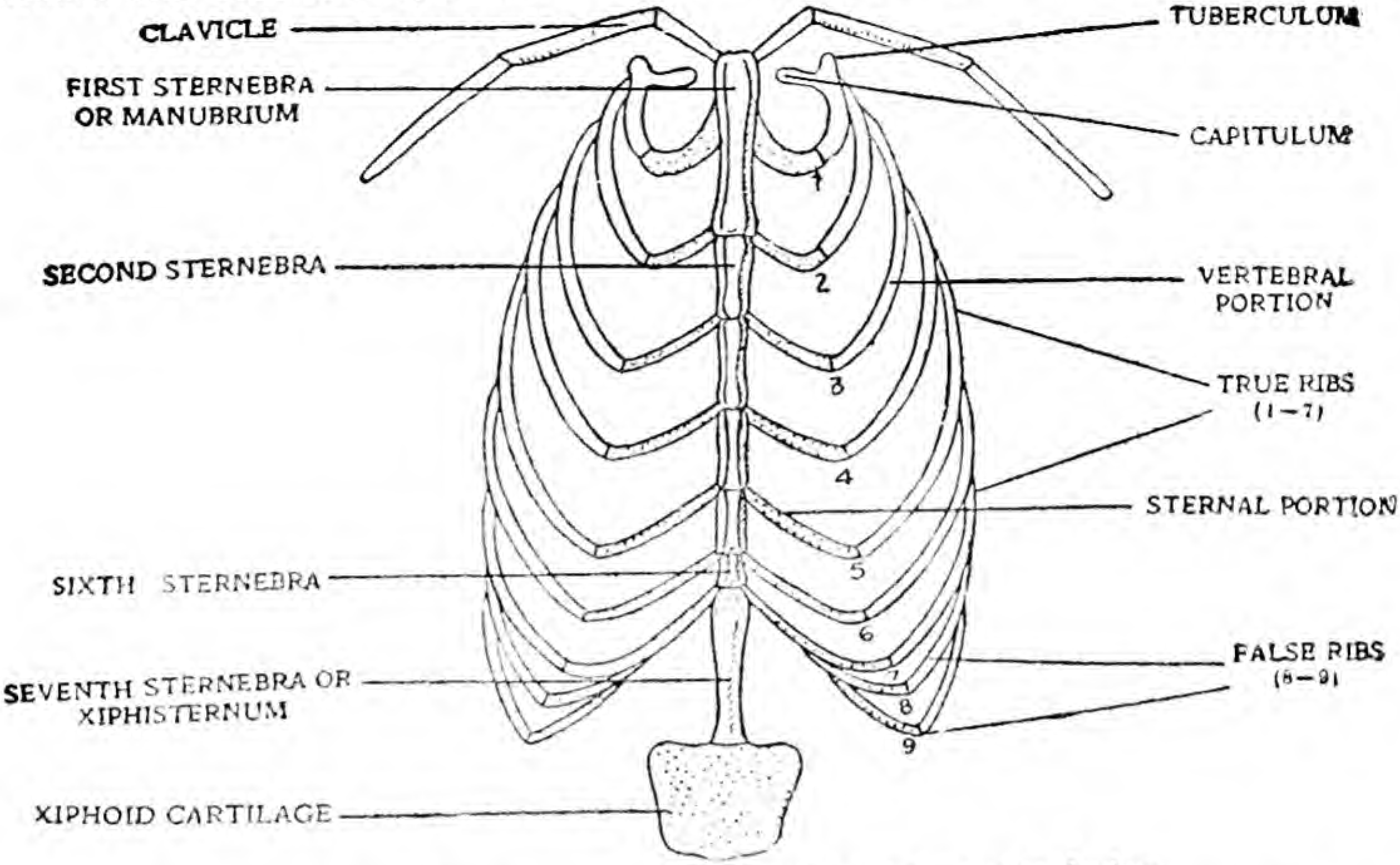


Fig. 17.17. The sternum and ribs of rabbit—ventral view

pairs of ribs in the rabbit (Figs. 17.2 and 17.17). The ribs of the first pair are the shortest. They increase in length up to the sixth rib and then again decrease. Each rib consists of two very unequal but distinct parts : the **vertebral part** and the **sternal part**.

The **vertebral part** is the dorsal larger bony part of the rib. It is directed outwards, downwards and backwards. The upper end of the vertebral part in the first nine pairs of ribs is forked into a **capitulum** which articulates with **capitular facets** on the adjacent centra and **tuberculum** which ariticulates with the tubercular facet on the underside of the

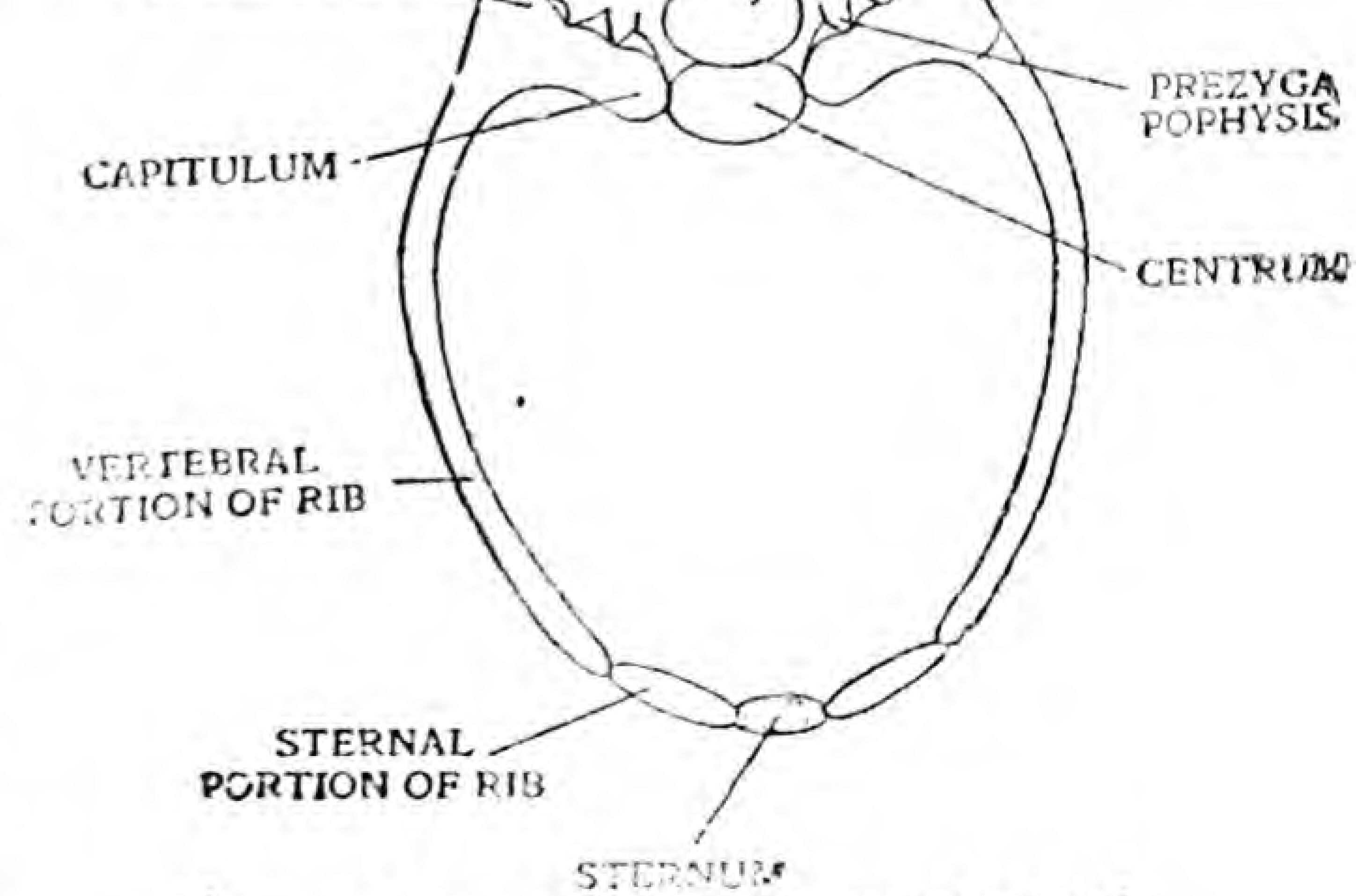


Fig. 17.18. A thoracic vertebra and a pair of ribs showing articulation

transverse process (Fig. 17.11). The remaining ribs are unforked and their ends or capitula articulate with the capitular facets present on the centra of the corresponding vertebrae. Except the first and the last four pairs of ribs, there is a small projection above the tuberculum for the attachment of ligaments.

The sternal part is ventral, smaller and cartilaginous. It is directed inwards, downwards and forwards. The sternal parts in the first seven pairs of ribs are directly connected with the sternum below. These are called the **true ribs.** The next two pairs of ribs are ventrally attached to the seventh pair and are called the **false ribs.** The last three pairs are free ventrally and are known as the **floating ribs.**

IV. Sternum

The **sternum** (Fig. 17.17) is a long, slender rod situated in the mid-ventral line of the thorax. It consists of seven bony pieces, the **sternebrae**, lying in a row one behind the other. The first sternebra is the largest and is called the **manubrium.** It is slightly expanded anteriorly and is produced ventrally into a longitudinal **ridge or keel.** The next four sternebrae are almost equal in size. The sixth sternebra is very small and sometimes invisible in the dried skeleton. The seventh sternebra is called the **xiphisternum.** It is long and slender, being next to the manubrium in size. It bears posteriorly a broad horizontal plate of cartilage, the **xiphoid cartilage.**

The anterior seven pairs of ribs articultate ventrally with the sternum. The first pair joins the manubrium at about the middle of its sides. The succeeding six pairs articulate at the joints between the sternebrae.

V. Girdles.

1. **Pectoral Girdle.** The pectoral or shoulder girdle of rabbit is greatly modified from its primitive structure which encircled the thorax for the protection of the lungs and the heart. It has lost its protective function due to the presence of ribs and serves to transmit the body weight to the limbs as the body is raised from the ground. The two halves no longer form an arch but separate. The term "**girdle**" is. thus, a misnomer here.

It lies obliquely outside the ribs and is attached to the axial skeleton only by muscles and ligaments. It consists of two main elements : the **scapula** and the **clavicle** (Fig. 17.19). The scapula is a thin, flat, triangular bone with its apex directed downwards and forwards and the base facing upwards and backwards. The apex bears a shallow pit, the **glenoid cavity**, where the head of the **humerus** articulates. The base bears a strip of cartilage, the **supra scapula.** The outer surface of the scapula bears a prominent longitudinal ridge, the **spine**, which is continued downwards as a narrow process, the **acromion.** The latter is free from the scapula. The acromion sends backwards another process, the **metacromion.** The spine, acromion and metacromion serve for the insertion of muscles. Overhanging the glenoid cavity is a hook-like **coracoid process.** This is a distinct bone in the young rabbit.

The clavicle is a slender curved bone attached by ligament to the manubrium of the sternum at one end and to the acromion process of the scapula at the other.

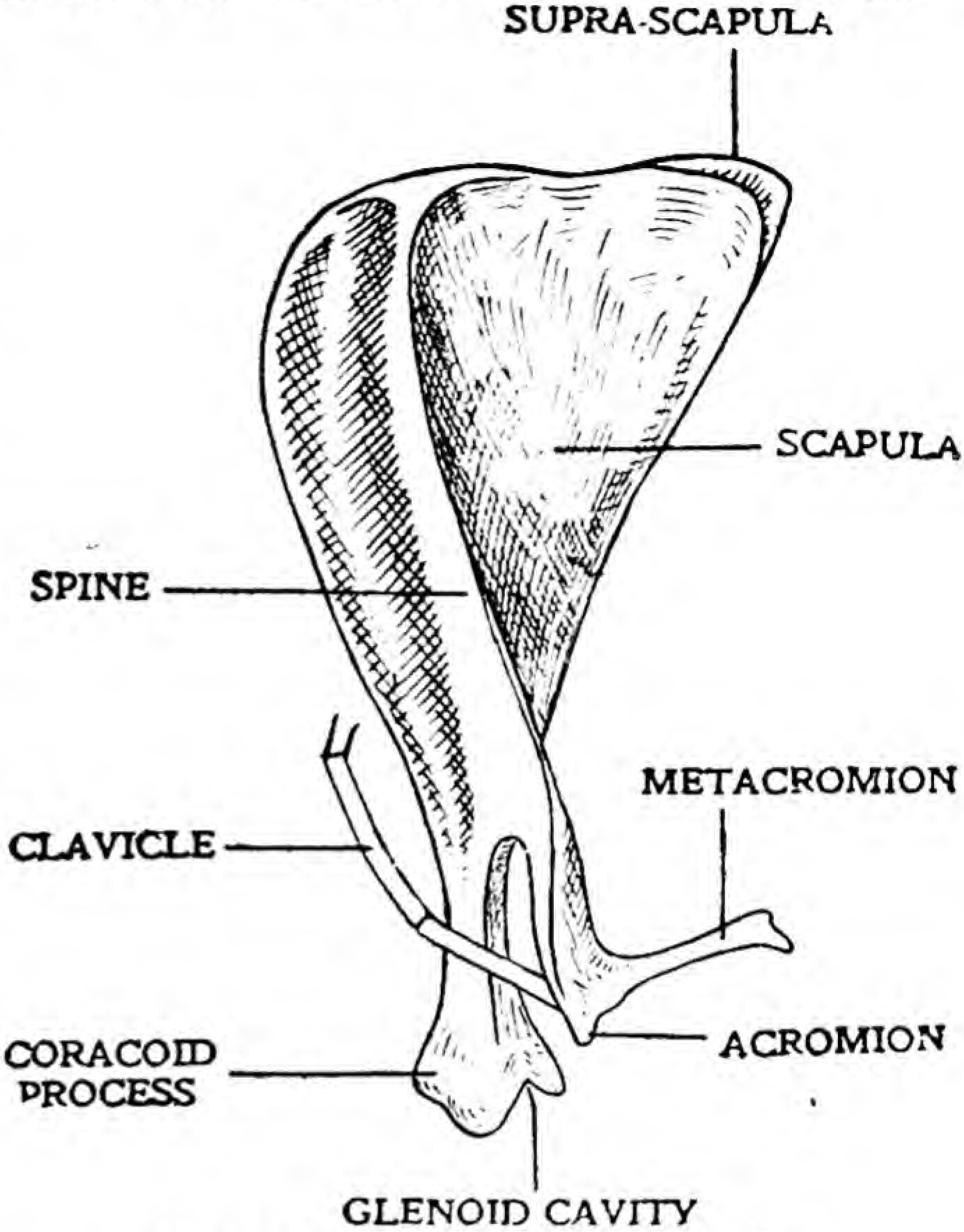


Fig. 17.19 The left pectoral girdle of rabbit—outer view

The fact that the pectoral girdle is embedded in the muscles and is without a bony joint with the axial skeleton makes it quite springy. This suppleness of the girdle reduces the shock of landing on the fore-limbs after a leap.

2. **Pelvic Girdle.** The pelvic or hip girdle is well-developed (Fig. 17.20). It consists of two halves which firmly articulate above with the sacrum and unite with each other in the mid ventral line. Their union is termed the **symphysis.** Each half of the girdle is usually called as **innominatum** or **innominate bone** and encloses a wide aperture, the **obturator foramen.** The right and left innominate bones consequently look like the letters "d" and "b" res-

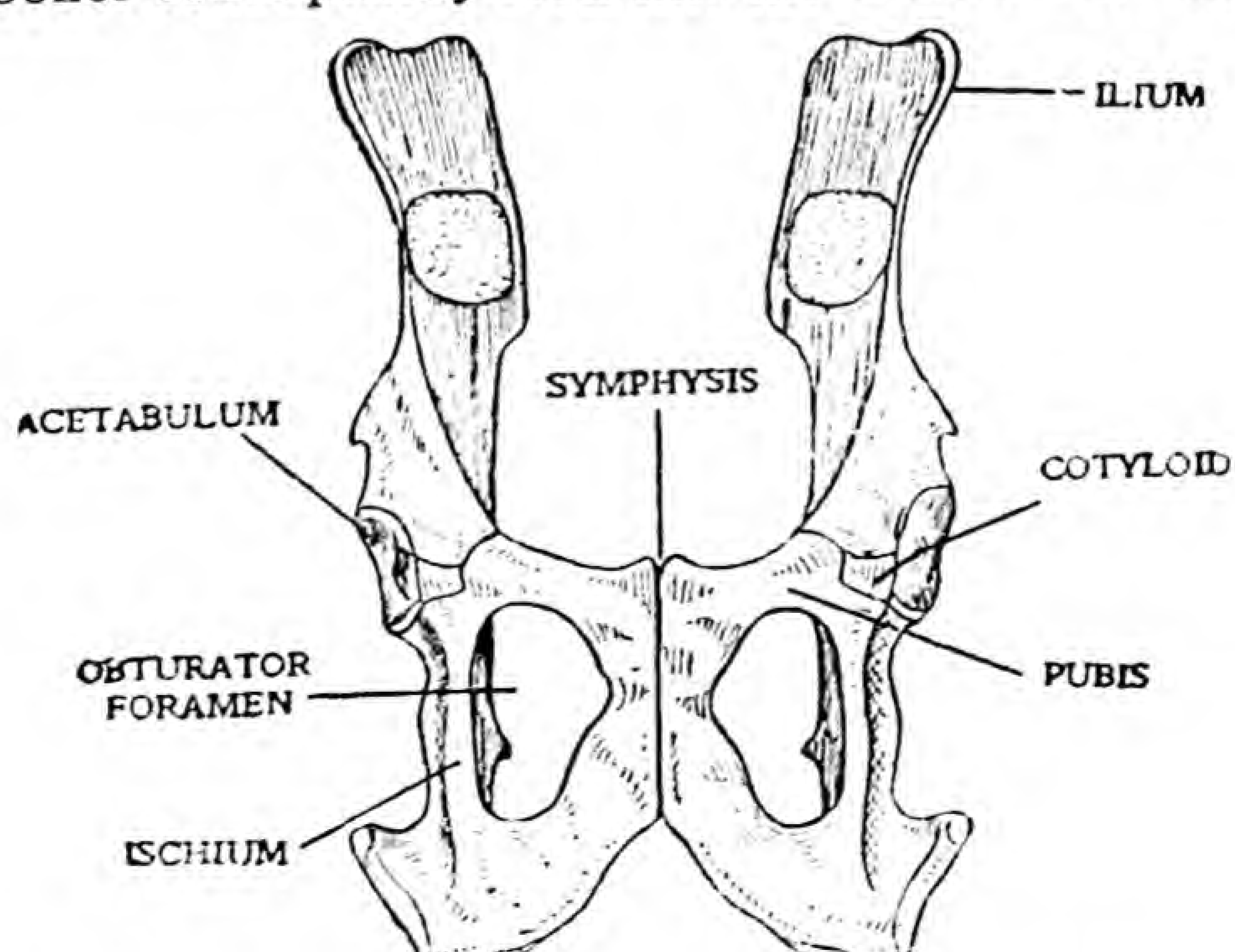


Fig. 17.20. The pelvic girdle of rabbit—ventral view

pectively. Each innominate consists of three components : the **ilium**, the **ischium** and the **pubis**, which lose all demarcations between them in the adult. A deep cup-shaped cavity, the **acetabulum**, is jointly formed by all the three bones of the innominate near the middle of its outer surface. The acetabulum lodges the head of the femur.

The ilium forms the anterior part of the innominate. It is narrow behind and expanded in front to articulate with the sacrum. It forms nearly half of the acetabulum.

The ischium forms the posterior and dorsal boundary of the obturator foramen. Its hinder end is expanded and thickened to form the **ischial tuberosity**. It forms about one-third of the acetabulum.

The pubis forms anterior and ventral border of the obturator foramen. The part of the pubis which shares in the formation of the acetabulum develops from a separate centre of ossification and is often called the **cotyloid bone**. It can be seen as a distinct bone in the skeletons prepared from the young animals.

The strength and rigidity of the pelvic girdle enable it to successfully withstand the thrust of the hind-limbs during jumping, while its position parallel to the backbone and its fusion with the sacrum enable it to transmit the thrust of the hind-limbs to the axis of the body without any loss of force.

VI. Bones of the Limbs

1. **Fore-limbs**. Each fore-limb has 30 bones, namely, **humerus** in the upper arm, **radius** and **ulna** in the fore-arm, 8 **carpals** in the wrist, 5 **metacarpals** in the palm and 14 **phalanges** in the fingers.

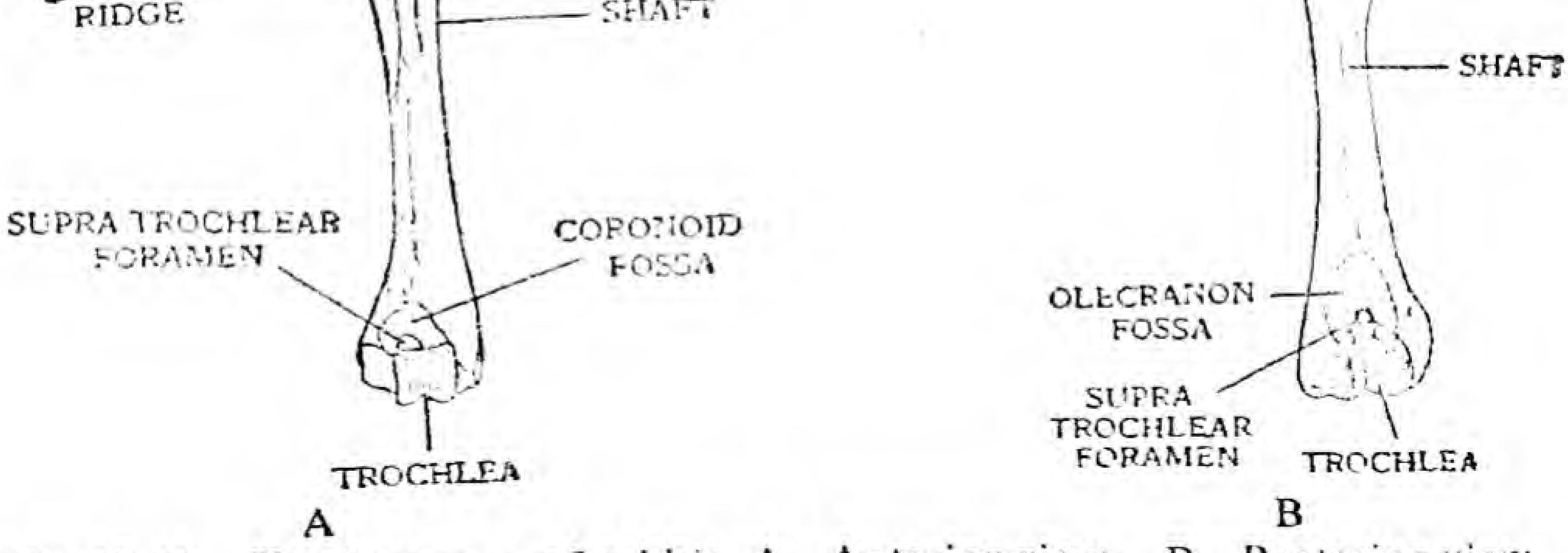


Fig. 17.21. The humerus of rabbit A. Anterior view. B. Posterior view.

The **humerus** (Fig. 17.21) is a long, stout bone differentiated into a smooth rounded head at the proximal end, a slender curved shaft in the

middle and a broad pulley-like trochlea at the distal end. The head articulates with the glenoid cavity of the scapula, forming a ball and socket joint. Just in front of the head are two elevations : the **lesser tuberosity** (which is the larger) on the inner side and the **greater tuberosity** on the outer side. Between the two tuberosities is a groove, the **bicipital groove**. The shaft bears on its anterior convex surface a sharp ridge, the **deltoid ridge**. The tuberosities, the bicipital groove and the deltoid ridge are meant for the attachment of muscles. The **trochlea** articulates with the bones of the fore-arm to form the **elbow joint**. Just above the trochlea on either side there is a depression called the **supratrochlear fossa**. The posterior supratrochlear fossa is larger and accommodates the olecranon process of the ulna. It is, therefore, also known as the **olecranon fossa**. The anterior supratrochlear fossa is smaller and is described as the **coronoid fossa**. The olecranon and coronoid fossae communicate with each other by an aperture, the **supratrochlear foramen**.

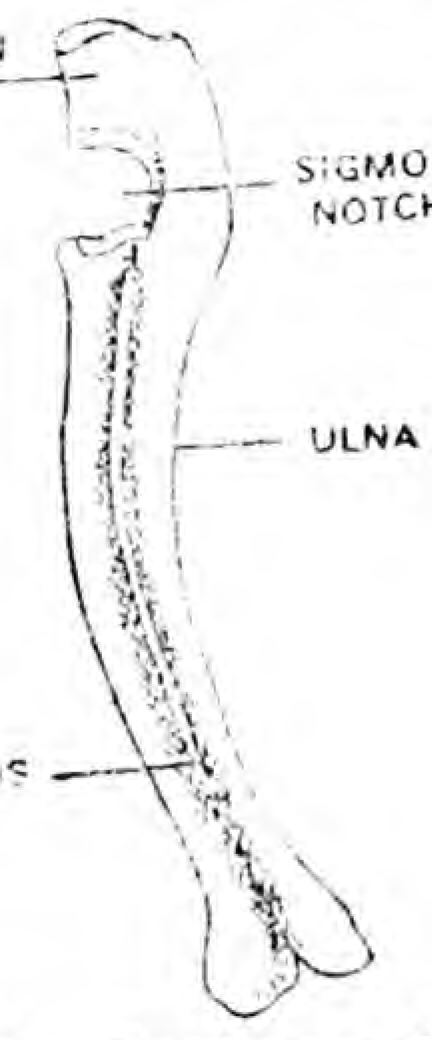


Fig. 17.22. The bones of the left fore-arm of rabbit lateral view.

The **radius** and **ulna**, which support the fore-arm, are long, slender curved bones firmly applied to each other all along their length (Fig. 17.22). They cross each other in such a way that their proximal halves lie behind each other and the distal halves side by side. They are permanently fixed in this condition so that the palm of the hand always faces downwards with the thumb pointing inwards.

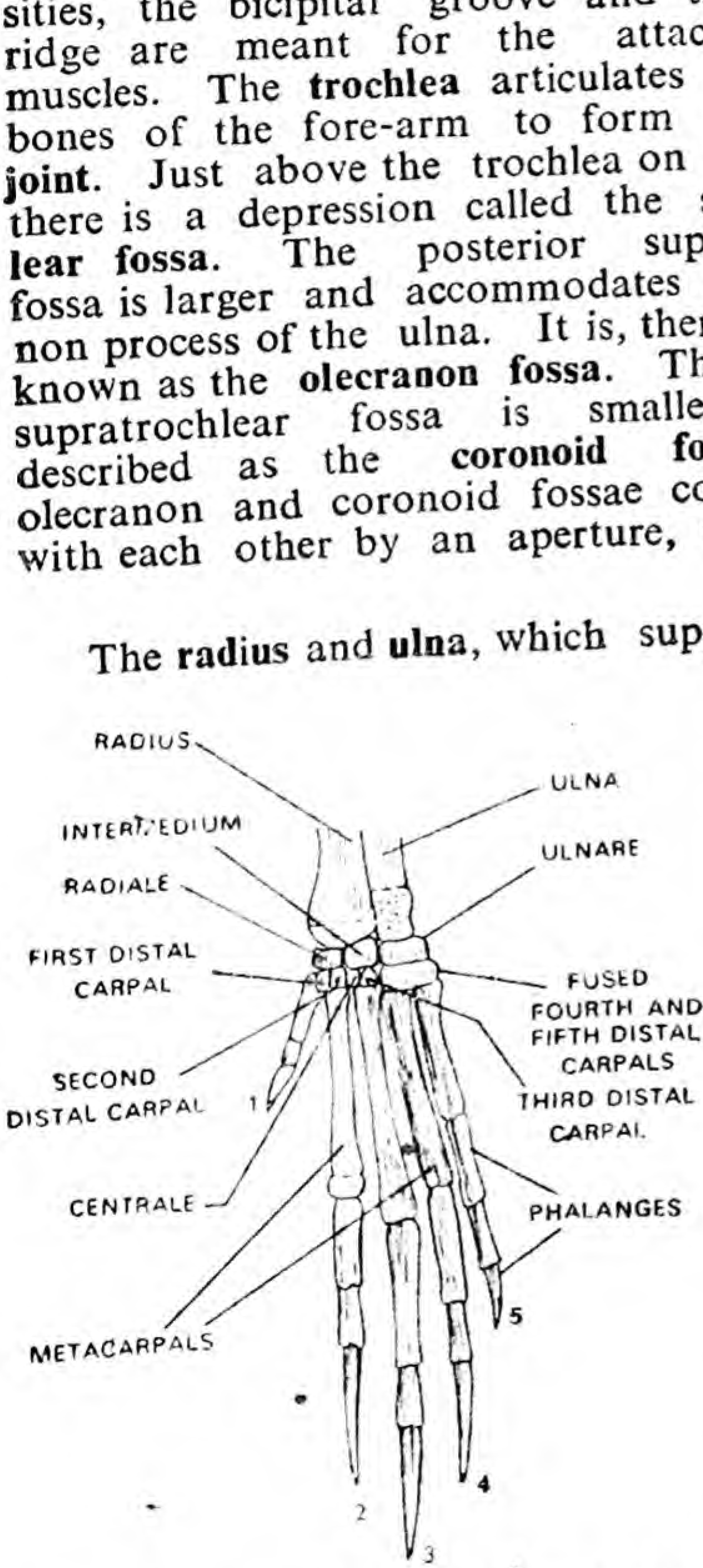


Fig. 17.23. Bones of the left fore-foot (manus) of rabbit—dorsal view

The **radius** is shorter than the ulna. Its proximal half lies in front of the ulna and the distal on the preaxial or inner side of the ulna. Its upper end is slightly broader and articulates with the trochlea and the ulna both. The lower end is much expanded and articulates with two carpal bones.

The **ulna** is prolonged beyond the radius proximally to form the **olecranon process** which bears a

deep notch, the **sigmoid notch**, on its anterior side. The sigmoid notch articulates with the trochlea. The distal end of the ulna is unexpanded and articulates with one carpal only.

The **carpals** are eight small bones in the **wrist** (Fig. 17.23). They are arranged in two rows : the proximal and the distal. The proximal row has three carpals : the **radiale** or **scaphoid**, the **intermedium** or **semilunar**, and the **ulnare** or **cuneiform**. The radiale lies on the preaxial side and articulates with the radius. The ulnare lies on the postaxial or outer side and articulates with the ulna. The intermedium lies between the two and articulates with the radius. The distal row comprises five carpals of which the middle one is called the **centrale.** It actually belongs to the middle row of carpals. The remaining four carpals are the **true distal** carpals. The first distal carpal or **trapezium** is squarish in outline and lies on the preaxial side of the wrist. It supports the first metacarpal. The second distal carpal or **trapezoid** is smaller and supports the second metacarpal. The third distal carpal or **osmagnum** is the smallest in the row and supports third metacarpal. The fourth and fifth distal carpals are fused to form the largest bone in the row, the **unciform**. It supports the fourth and fifth metacarpals.

Besides the above-mentioned true carpals, the wrist also bears a small **sesamoid** bone on its underside. It is called the pisiform and articulates with the ulna and ulnare.

The **metacarpals** (Fig. 17.23) are long slender bones of unequal size. They support the palm.

The **phalanges** (Fig. 17.23) support the digits. The first or the preaxial digit, called the **pollex**, is the shortest and contains only two phalanges. All other digits have three phalanges each. The terminal phalanx of each digit is pointed and curved to support the horny claw on it.

Small nodule-like sesamoid bones are found on the underside of the digits in connection with the joints between the metacarpals and the first phalanges and also between the second and third phalanges. They afford extra strength to the digits during burrowing.

The rabbit cannot rotate its fore-arm as man can do. Therefore, its hand is fixed in pronate position, *i.e.* with the palm facing downwards, and cannot be placed in **supinate position**, *i.e.* with palm upwards. Pronate condition gives the hand greater strength during burrowing. The hands touch the ground with the digits only. This fact together with the bend at the elbows of the fore-limbs reduces considerably the shock of landing on the ground after a leap.

2. **Hind-limbs**. Each hind-limb has 25 bones, *viz.* **femur** in the thigh, **tibia** and **fibula** in the shank, 6 **tarsals** in the ankle, 4 **metatarsals** in the instep and 12 **phalanges** in the toes.

The **femur** (Fig. 17.24) has a long, stout, curved shaft which is somewhat expanded at either end. The proximal end bears a smooth round-

ed head and three rough projections : the greater, lesser and third **trochanters**. The head articulates with the acetabulum of the pelvic girdle to form the hip-joint. The greater trochanter lies right at the upper end of the shaft, the lesser trochanter just below the head and the third trochanter below the greater trochanter on the outer side of the shaft. There is a deep pit, the **trochantric** or **digital fossa**, between the greater trochanter and the head on the posterior side of the bone. The trochanters are meant for the insertion of muscles. The distal end of the femur shows two large condyles enclosing a deep notch, the **intercondylar groove**, between them. The condyles articulate below the tibia. The intercondylar groove is continuous round the edge of the bone with another groove, the **patellar groove**, present on the front side of the bone. A large sesamoid bone, the **patella** or knee-cap, slides in the patellar groove. It is attached to the tibia by ligaments.

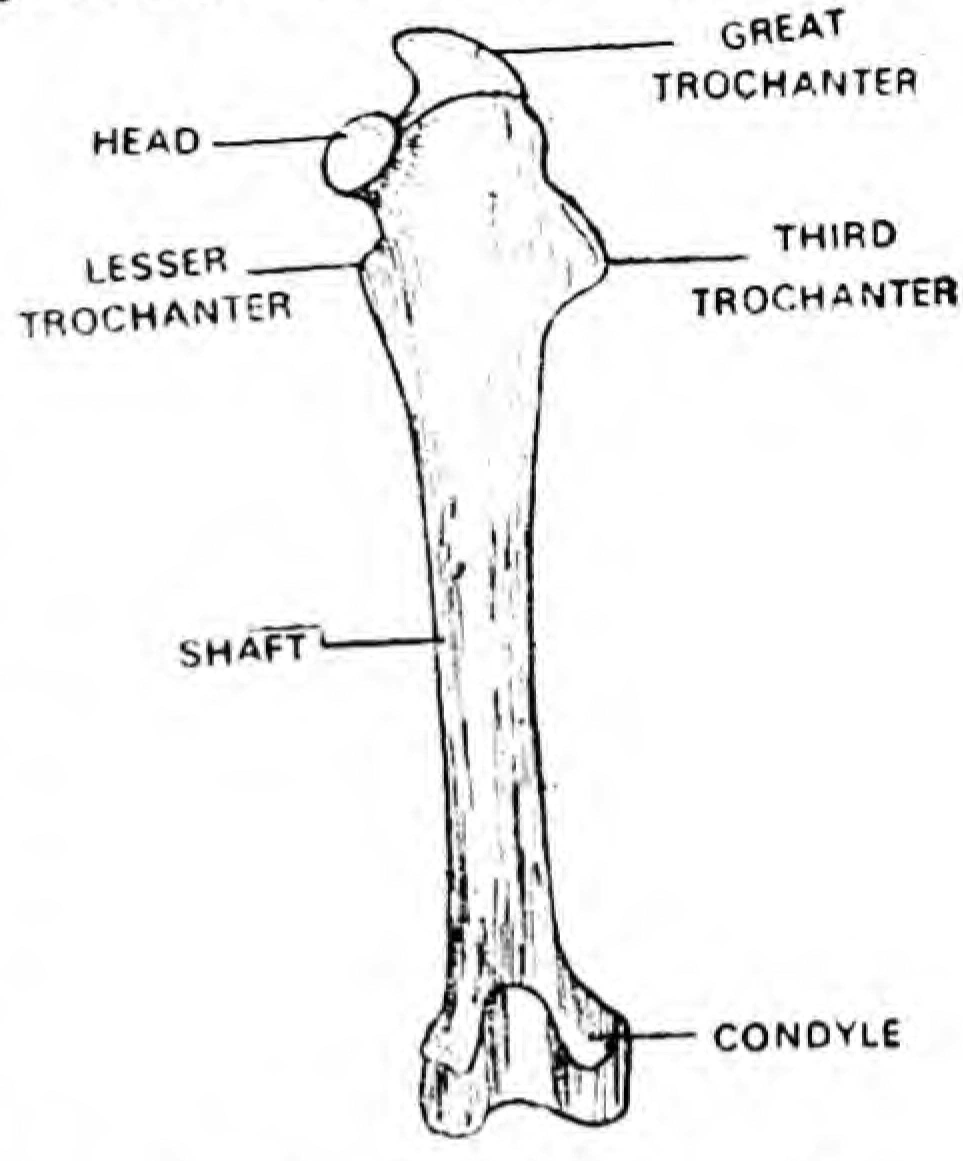


Fig. 17.24. Left femur of rabbit—anterior view

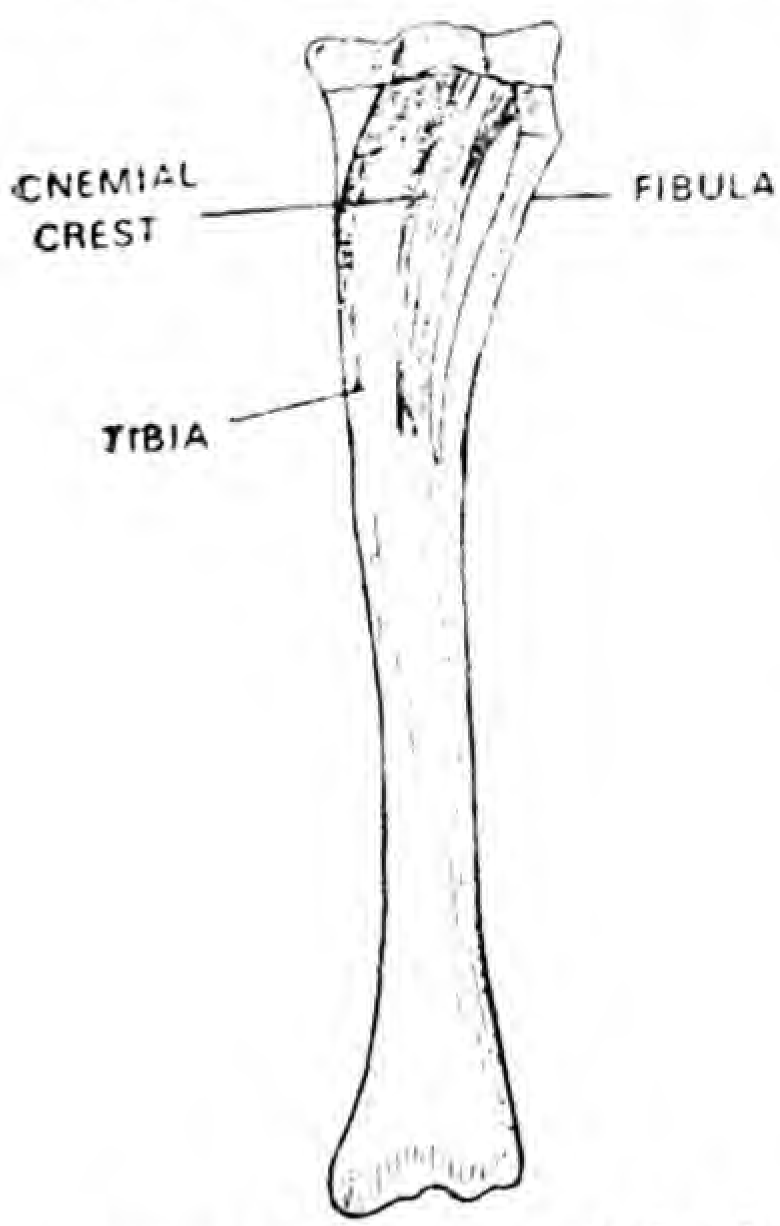


Fig. 17.25. Bones of the left leg or shank of rabbit

The **tibia** and **fibula**, which support the leg, are fused together in their distal halves to make the hind-limbs more rigid (Fig. (17.25).

The **tibia** is a thick, strong, straight bone lying on the inner side. It is the longest bone in the body. On the top of its proximal end, it bears two concave facets for articulation with the condyles of the femur A prominent longitudinal ridge **cnemial crest**, is developed on the proximal half of its anterior surface. Its distal end has an articular surface for the astragalus.

The **fibula** is a very thin and weak bone situated on the outer side. Its proximal free end articulates with the tibia while the distal end, which is fused with the tibia, articulates with the calcaneum.

The **tarsals** (Fig. 17.26) are six small bones in the ankle. They are arranged in three rows : the proximal, middle and distal The proximal row contains two tarsals : the inner smaller **astragalus** and the outer longer **calcaneum**. The astragalus articulates above with the tibia by a pulley-like surface. It is considered to represent two fused bones, the **tibiale** and **intermedium**, of the typical tarsus The calcaneum articulates above with the fibula. It is produced backwards

into a strong calca neal process to form the heel.

The central row has only one tarsal called the **centrale** or **navicular.** It has shifted from its normal position to the inner side of the tarsus so that it lies just in front of the astragalus. It bears a long forwardly projecting process on the ventral side of the tarsus.

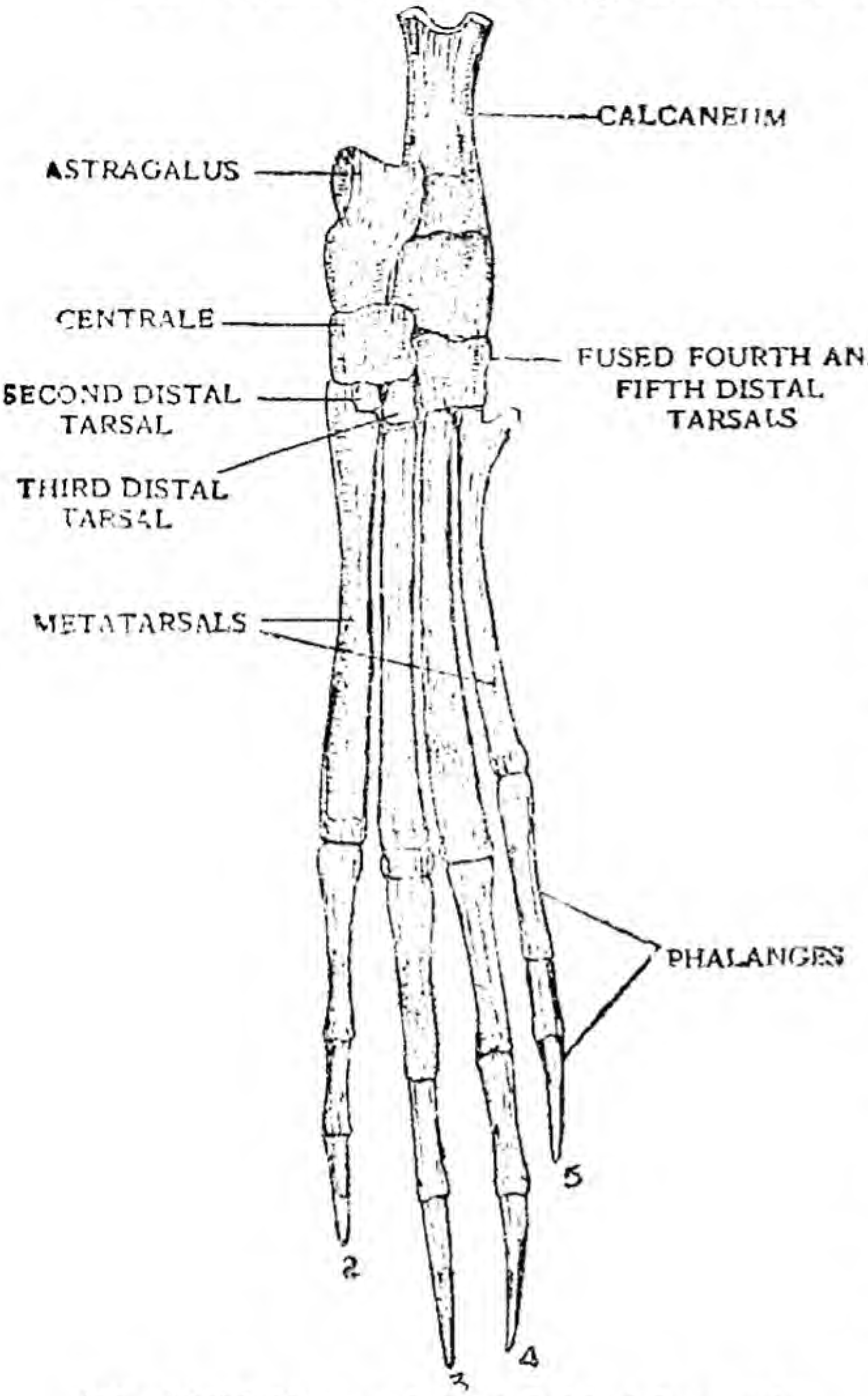


Fig. 17.26 Bones of the left hind-foot of rabbit—dorsal view

The distal row is made up of three **tarsals.** The first distal tarsal or **entocuneiform** is missing due to the absence of the first digit or **hallux.** The second distal tarsal or **mesocuneiform** is the smallest in the row and supports the second metatarsal. The third distal tarsal or **ectocuneiform** is large and supports the third metatarsal. The fourth and fifth distal tarsals are fused to form the largest bone in the row, the **cuboid.** It supports the fourth and fifth metatarsals.

The **metatarsals** (Fig. 17.26) are four (second to fifth) long slender bones of variable size in the instep. The inner or second metatarsal sends a process from its proximal end to meet the centrale. The process is a distinct bone in the young rabbit and is thought to represent the missing first distal tarsal and the first metatarsal of the adult. The fifth metatarsal shows an outwardly-directed projection at its proximal end.

The **phalanges** (Fig. 17.26) are twelve small bones, three in each digit. The terminal phalanx of each digit is pointed and curved to support the horny claw on it.

Small nodule-like sesamoid bones are developed on the underside of the foot in connection with the joints between the metatarsals and the first phalanges and also between the second and third phalanges.

As compared with the hand, the entire foot meets the ground during progression. Large surface of the feet in contact with the ground together with the long segments of the hind-limbs bent like a spring (Z),

increase the thrust produced on sudden straightening of the limbs for leaping.

TABLE 8

SUMMARY OF BONES OF RABBIT

Skull	Cranium	Occipital Segment	1 Basioccipital	—below foramen magnum
			2 Exoccipitals	—on sides of foramen magnum.
			1 Supraoccipital	—above foramen magnum
		Parietal Segment	1 Basisphenoid	—ventral, triangular
			2 Alisphenoides	—lateral, wing-like
			2 *Parietals	—dorsal, squarish
			1 *Interparietal	—dorsal, very small
		Frontal Segment	1 Presphenoid	—ventral, laterally-compressed
			2 Orbitosphenoids	—lateral
			2 *Frontals	—dorsal, rectangular
			1 Cribriform plate	—anterior, vertical, perforated
	Sense Capsules	Auditory Capsules	2 Periotics	—each with two parts : inner petrous, outer mastoid
			2 *Tympanics	—each with two parts : lower bulla, upper meatus
			6 Ossicles	—I malleus, I incus and I stapes in each bulla
		Olfactory Capsules	2 Nasals*	—dorsal
			1 Vomer*	—mid-ventral, two fused into one
			1 Mesethmoid	—median vertical partition
			6 Tubinals*	—folded, project into nasals chambers
		Optic Capsules	2 *Lacrymals	—very small, at antero-dorsal angle of orbit
	Jaws	Upper Jaw	2 *Premaxillae	—anterior, bear incisors, each with upper nasal and lower palatine processes
			2 *Maxillae	—irregular, fenestrated, bear premolar and molars, each with alveolar, palatine and zygomatic processes.
			2 *Jugals	—laterally compressed bones in the zygomatic arches
			2 *Palatines	—each with palatine process
			2 *Pterygoids	—behind palatines
			2 *Squamosals	—irregular, in front of auditory capsule, each with zygomatic and posttympanic processes
		Lower Jaw	2 *Dentaries	—vertical, triangular plates, each with condyle, coronoid process and angular process
	Hyoid Apparatus		1 Basihyal	—supports throat, bears short anterior and long posterior cornua

*The bones bearing the asterisk mark are membrane bones. Others are cartilage bones.

Vertebral Column (about 45 vertebrae in all, all amphiplatyan, with epiphyses			7 Cervical Vertebrae—transverse processes pierced by vertebrarterial canals, support neck. 12 Thoracic Vertebrae—centra bear capitular facets for ribs, slender, support thorax 6 or 7 Lumbar Vertebrae —transverse processes directed downwards and forwards stout, support abdomen 3 or 4 Sacral Vertebrae—fused to form sacrum to support hip region 16 Caudal Vertebrae—small, gradually become reduced backwards, support tail.
Costae or Ribs (12 Pairs)			7 True Ribs —articulate below with the sternum. 2 False Ribs —articulate below with the 7th pair of ribs. 3 Floating Ribs —free ventrally.
Sternum			7 Sternebrae —small bony rods of different size, form mid-ventral axis. 1 Xiphoid Cartilage—broad plate behind 7th sternebra.
Pectoral Girdle			1 Scapula —a broad triangular plate with cartilaginous supra-scapula above and glenoid cavity below, bears a spine and three processes : coracoid, acromion and meta-cromion. 1 Clavicle—a slender curved rod
Fore-limb	Upper arm (Brachium)		1 Humerus —a stout rod with head, shaft and trochlea.
	Fore-arm (Antebrachium)		1 Radius —shorter, pre-axial 1 Ulna —longer, post-axial, with olecranon process and sigmoid notch
	Hand (Manus)	Wrist (Carpus)	8 Carpals—3 proximal carpals (radiale, intermedium and ulnare), I centrale and 4 distal carpals 1 Pisiform—a ventral sesamoid bone
		Palm (Metacarpus)	5 Metacarpals—slender bones of unequal size
		Fingers (Digits)	15 Phalanges—2 in pollex, 3 in each of the rest ∝ Sesamoids—small nodules on the underside at the joints
Pelvic Girdle (Innominate)			1 Ilium —forms antero-dorsal part 1 Ischium —forms postero-dorsal part 1 Pubis —forms anterior and ventral borders of obturator foramen (all the three form acetabulum).

Hind-limb	Thigh		1 Femur —a stout bone with head, trochanters, shaft and condyles.
	Shank		1 Tibia —thicker, pre-axial, with cnemial crest. 1 Fibula —slender, post-axial, fused with tibia distally. 1 Patella —a sesamoid bone covering knee-joint in front.
	Foot (Pes)	Ankle (Tarsus)	6 Tarsals —2 proximal tarsals (astragalus and calcaneum), 1 central tarsal or centrale, 3 distal tarsals.
		Sole or Instep (Metatarsus)	4. Metatarsals—slender bones of unequal size.
		Toes (Digits)	12 Phalanges—3 in each digit. ∝ Sesamoids—small nodules on the underside at the joints.

TEST QUESTIONS

1. What are 'membrane bones', 'replacing bones', and 'sesamoid bones'. Give examples of each kind.
2. Give an account of the girdles of rabbit. What are the girdles meant for ?
3. Describe the basic structure of a vertebra. Name the various types of vertebrae found in rabbit. Give the distinguishing characters of each kind.
4. Write all you know about the skeleton of thorax in rabbit.
5. Give an account of the bones of the fore -or hind-limb of rabbit.
6. Give a brief description of the skull of rabbit.
7. Describe the histological structure of the mammalian bone.

CHAPTER **18**

Oryctolagus cuniculus

(The Rabbit)

DIGESTIVE SYSTEM

The primary function of the digestive system is to provide food to the body tissues for use in growth, maintenance and production of energy. Besides this, a small anterior region of the system (pharynx) forms a part of the respiratory system and some parts of the system remove unwanted materials from the body.

Morphology of Digestive System

The digestive system can be divided for the sake of convenience in description into two main parts : the **alimentary canal** or **digestive tract,** in the cavity or **lumen** of which the food is digested and the **digestive glands** which provide important secretions for digestion.

1. **Alimentary Canal.** The alimentary canal is a long, coiled tube of varying diameter (Fig. 18.4). It is suspended in the body-cavity or eoelom from the dorsal body-wall by a double fold of peritoneum. It is complete and consists of several organs which, in sequence from before backwards, are : **mouth, vestibule, buccal cavity, pharynx, oesophagus stomach, small intestine, large intestine** and **anus.** Of these, the vestibule and buccal cavity are lined with ectoderm and form the **stomodaeum** posterior part of the large intestine (rectum) is likewise lined with ectoderm and constitutes the **proctodaeum** ; while the rest are lined with endoderm and form the **mesodaeum.**

(*i*) **Mouth.** The mouth is a relatively small transverse slit at the lower or anterior end of the head. It is bounded by two soft, movable and hairy **lips** : upper and lower. The lips are covered with skin on the outside and lined with mucous membrane on the inside. The upper lip, termed the **hare lip,** has in its middle a verticle cleft which connects the mouth with the external nares above and exposes the front upper teeth.

(*ii*) **Vestibule.** The vestibule is a narrow space enclosed between the lips and cheeks externally and gums and teeth internally. Its lining contains mucous glands.

(*iii*) **Buccal Cavity.** The buccal cavity is bounded above by the **palate** (Figs. 18.1 & 18.2), below by the **throat** and on the sides by the jaws. The anterior part of the palate is strengthened by bony processes of the jaw bones and is called **hard palate.** It has transverse ridges, the **rugae.** At is anterior end, it is perforated by a pair of openings, the

nasopalatine canals, which connect the buccal cavity with the nasal chambers above. The posterior part of the palate is smooth and fleshy and is termed the **soft palate**. The hind free end of the soft palate hangs down as a small flap, the **uvula**. Many small mucous glands are located on the palate. The buccal cavity contains a few important structures like the tongue, teeth and openings of salivary glands.

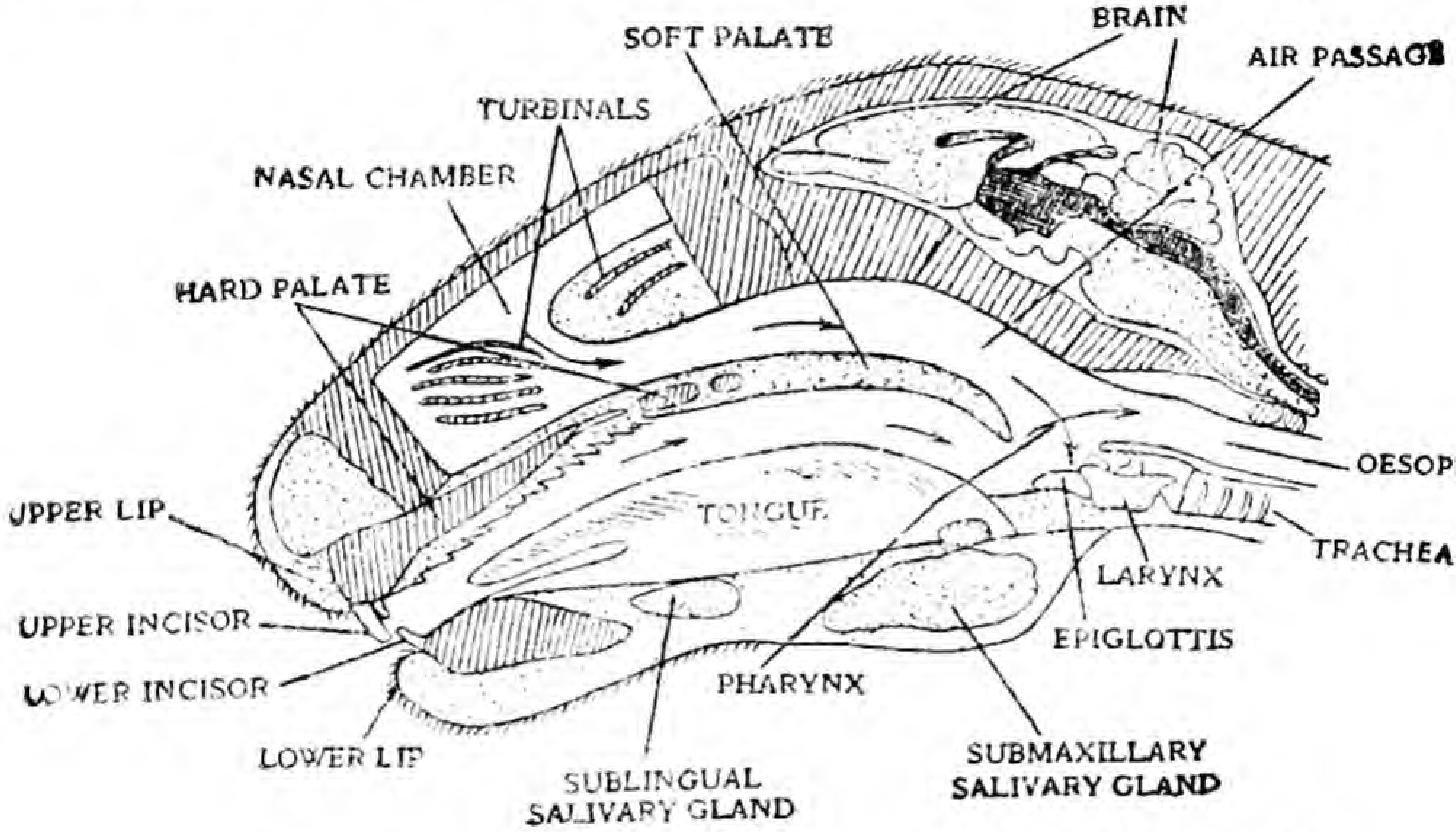


Fig. 18.1. Sagittal section of the head of the rabbit

(a) **Tongue.** The tongue is a long, highly muscular organ attached to the floor of the buccal cavity along the greater part of its length. Its anterior end is free and capable of slight protrusion. The posterior half of the tongue is hard and bears laterally two pairs of large papillae, the **circumvallate papillae** near the hind end and the **foliate papillae** near the middle. Each circumvallate papilla is surrounded by a trench. The anterior half of the tongue is soft and bears numerous small finger like papillae on the edges and the tip. All the papillae contain taste buds. Besides being an organ of taste, the tongue also aids in chewing by placing the food in position under the teeth and helps in swallowing by pushing the food-bolus backwards. It also bears mucous glands.

(b) **Teeth.** The teeth are present in both the jaws (Figs. 17.2, 17.4 and 18.2.). They are embedded in **sockets** or **alveoli** of the jaw bones and are described as **thecodont**. Their number is fixed and they are produced in two sets : the **milk teeth** and the **permanent teeth**. The milk teeth are developed early in life and are soon replaced by the permanent teeth. The teeth of rabbit are, thus, **diphyodont**. They are also **heterodont**, *i.e.* they are differentiated into various types, viz. **incisors**, **premolars** and **molars**. The incisors or the cutting teeth have sharp cutting edges and occur at the anterior tips of the jaws. Behind the incisors is a wide toothless space, the **diastema**. This place is occupied by pointed teeth, the **canines**, in other mammals. The premolars and molars, both called the **grinding teeth**, have broad tops and are located further back in the

jaws. They are similar except that the molars lack milk predecessors. The upper jaw bears two pairs of incisors, three pairs of premolars and three pairs of molars. The lower jaw has only one pair of incisors, two pairs of premolars and three pairs of molars. The four incisors of the upper jaw are in two rows, two larger ones in the front row and two shorter ones

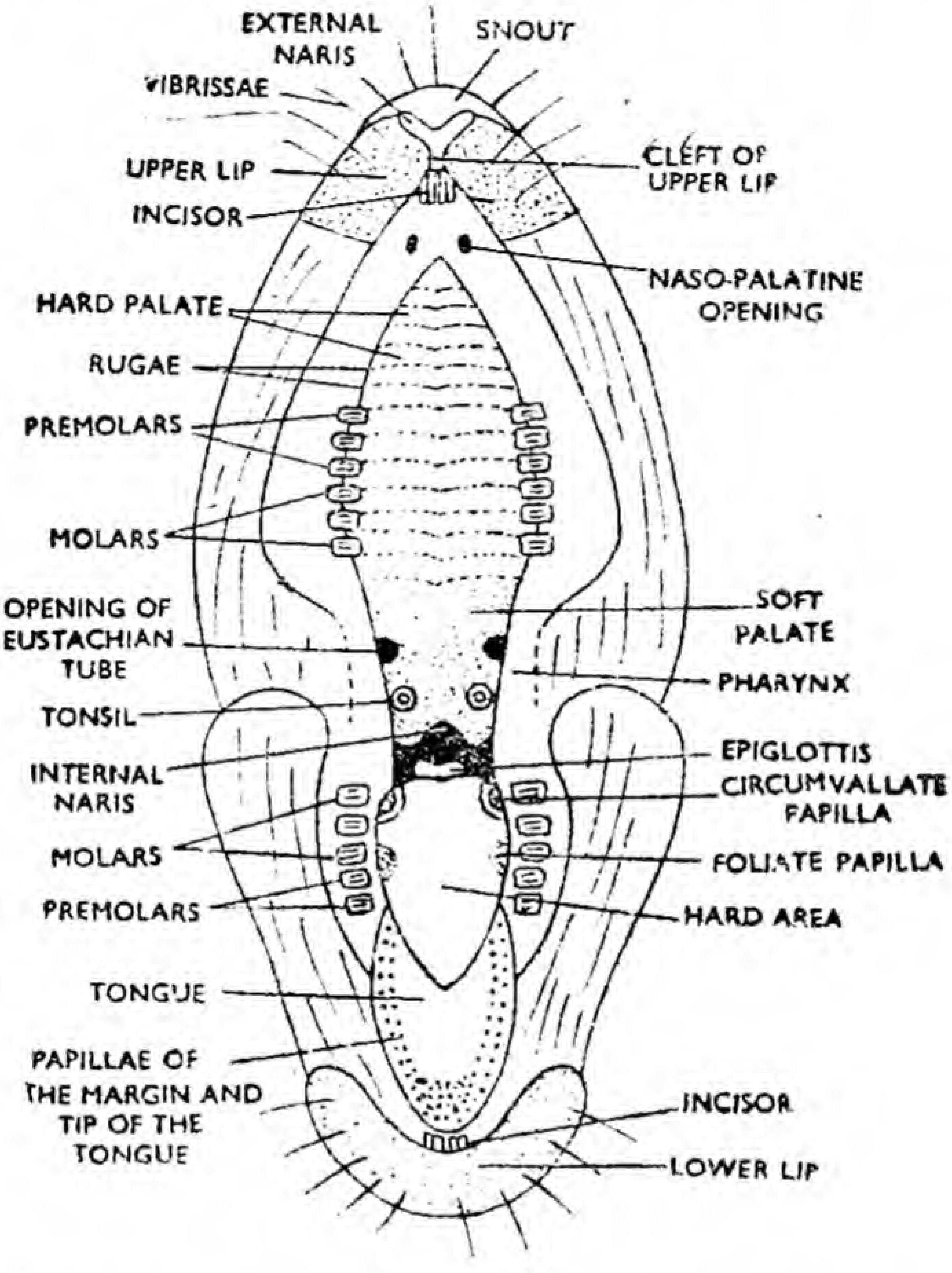


Fig. 18.2. Buccal cavity and pharynx of rabbit

in the hind row. The mammalian dentition is expressed by a dental formula which for the rabbit is $i\,\frac{2}{1},\ \ c\,\frac{0}{0}\ ,\ pm\ \frac{3}{2},\ m\ \frac{3}{3}=28$. The letters *i*, *c*, *pm.* and *m* refer to the incisors, canines, premolars and molars respectively. The figures above and below the lines indicate the number of teeth in one half of the upper and lower jaws. The formula, thus, gives half of the total number of teeth. This is doubled to determine the true number.

A tooth (Fig 18.3) is formed of a hard substance called **dentine** or ivory and consists of three regions : the **crown** or the exposed region, the **neck** or the region embraced by the gums and the **root** with one or more **fangs** embedded in the socket. The crown is covered by a

white shining **enamel** while the neck and the root are enclosed by **cement.** In the centre of the tooth there is a **pulp cavity** filled with connective tissue, blood-vessels and nerves. The pulp cavity has an aperture at the base. The aperture remains open permanently to enable the tooth to continue its growth throughout life. Such teeth are said to be "**rootless**" or with **persistent pulp.**

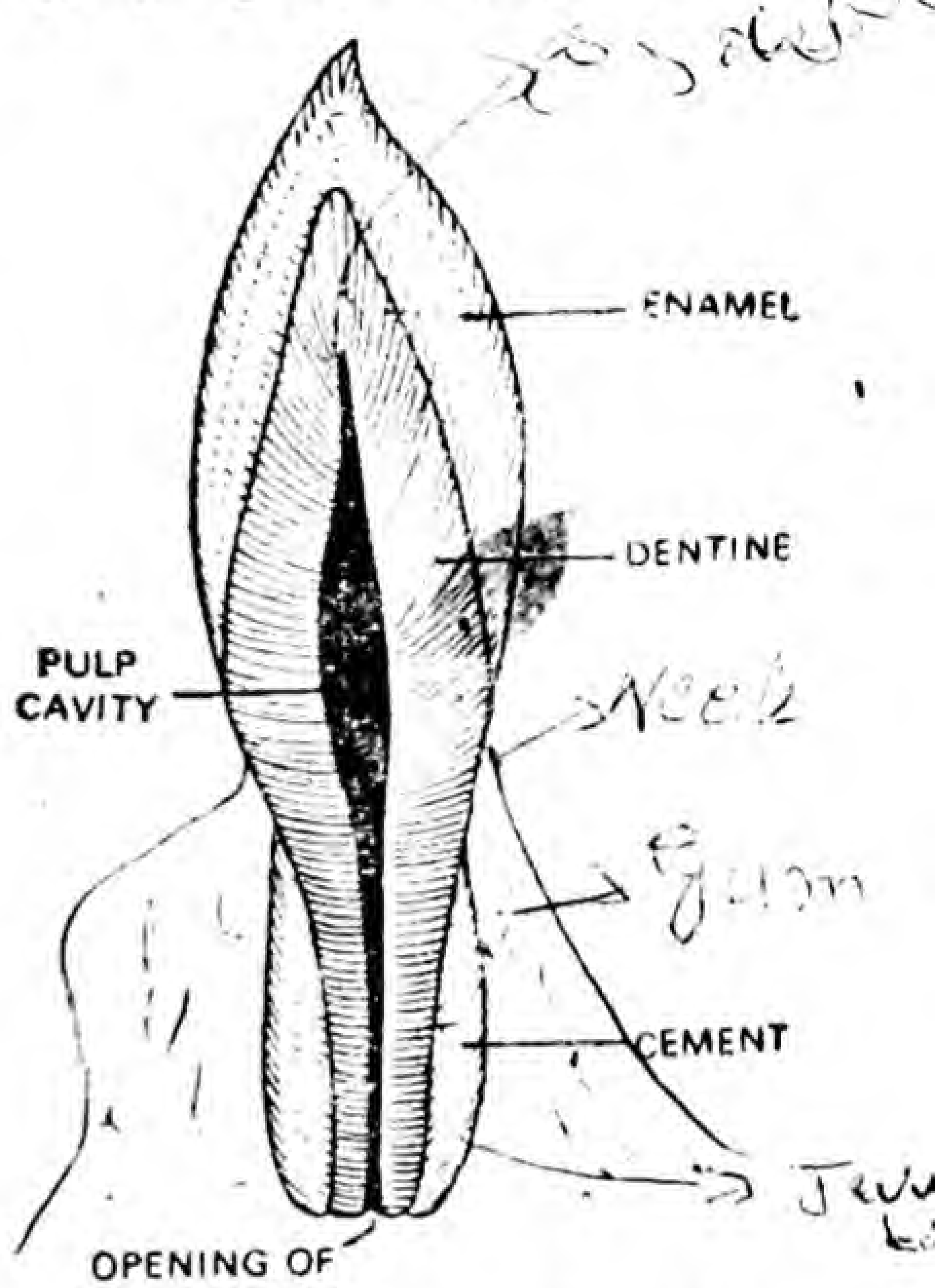


Fig. 18.3. Vertical section of a tooth of rabbit.

(*iv*) **Pharynx.** The pharynx has two parts : the upper **nasopharynx** and the lower **oropharynx.** The former has a common aperture of the internal nares in front and the openings of the Eustachian tubes on the sides. The oropharynx receives the buccal cavity and leads posteriorly into the **food pipe** or **oesophagus** dorsally and the **voice-box** or **larynx** ventrally. The opening to the larynx is called **glottis.** It bears a leaf-like cartilaginous flap, the **epiglottis,** to prevent the entry of food into it. The pharynx contains in its wall the muscles that initiate swallowing movements.

(*v*) **Oesophagus.** The oesophagus is a long, narrow, straight, muscular tube. It extends backwards through the neck and the thorax, pierces the diaphragm to enter the abdomen, and opens into the stomach. Its beginning remains almost closed, except during swallowing of food, to prevent the air going into it during breathing.

(*vi*) **Stomach.** The stomach is a wide, curved sac lying transversely across the anterior part of the abdomen. The end of the stomach that receives the oesophagus is called the **cardiac end** while the end that joins the intestine is termed the **pyloric end.** The middle main part of the stomach is called the **body.** The cardiac end is prolonged anterior to the entrance of the oesophagus into it and is termed the **fundus.** The latter initiates the wave-like contractions of the stomach wall. The posterior convex and the anterior concave faces of the stomach are respectively known as the **greater** and **lesser curvatures.** Opening of the oesophagus into the stomach is guarded by a valve, the **cardia,** which prevents the regurgitation of food. The wall of the stomach is thick and highly muscular. Its mucous lining is raised into ridges and contains numerous microscopic **gastric glands** (Figs. 5.28 and 5.29). The pyloric portion leads into the small intestine by an aperture guarded by a thick ring-like sphincter muscle called the **pyloric valve** or **pylorus.**

(*vii*) **Intestine.** The intestine is a narrow tube comprising three parts : **duodenum, jejunum** and **ileum.** The duodenum follows the

stomach and is U-shaped. It receives the bile-duct only a short distance from the pylorus and the pancreatic duct a bit in front of its forward turn. The jejunum and ileum form about two-fifths and three-fifths of the small intestine respectively. They are greatly coiled. The small intestine is the longest part of the alimentary canal, being two to three metres in length. In order to be accommodated in a short space, it is greatly coiled. Its mucous lining is raised into numerous finger-like projections, the **villi**, which increase its surface tremendously. The wall of the small intestine has numerous microscopic **intestinal glands.** At

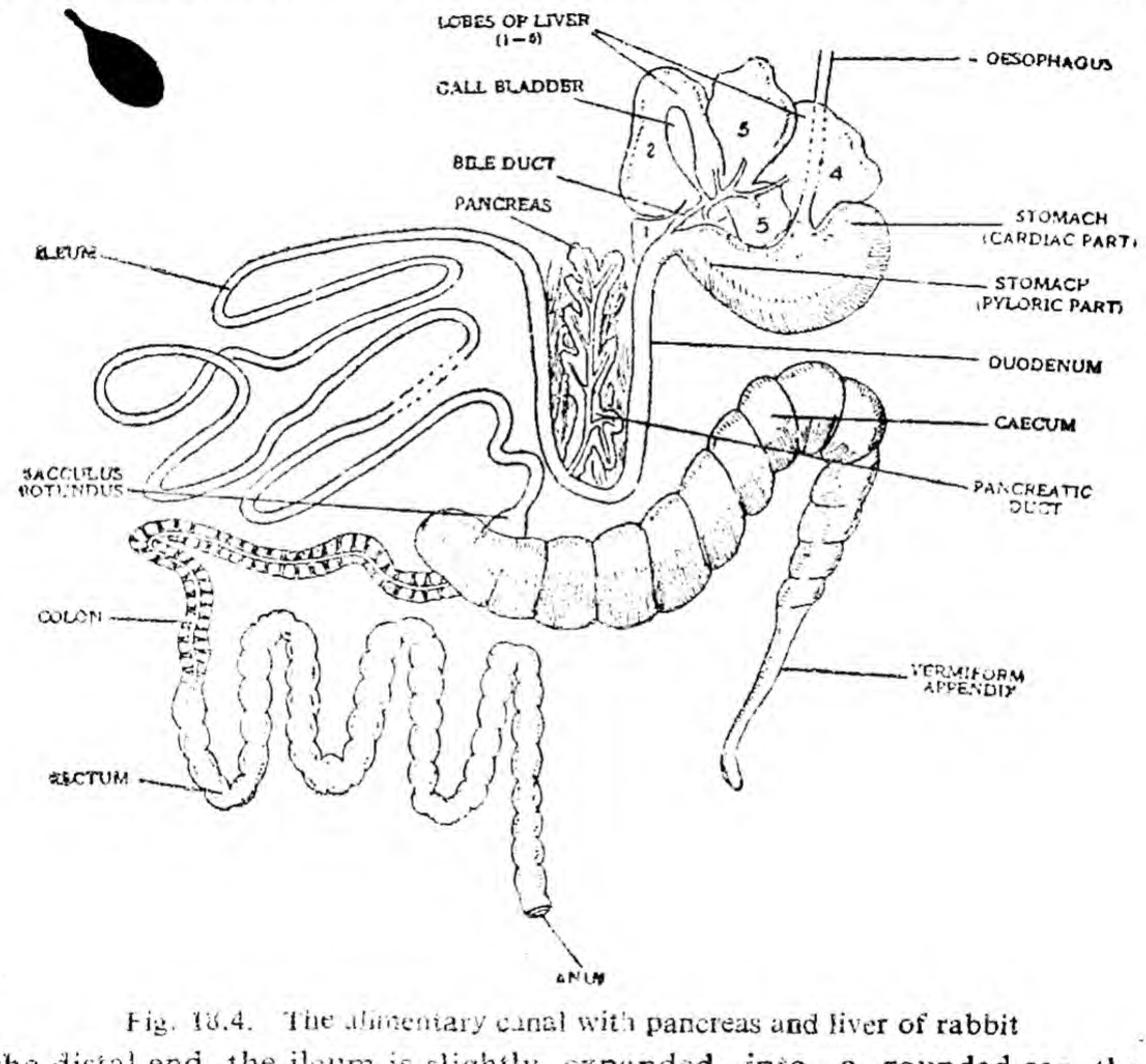


Fig. 18.4. The alimentary canal with pancreas and liver of rabbit

the distal end, the ileum is slightly expanded into a rounded sac, the **sacculus rotundus**. The latter opens into the caecum. The sacculus rotundus has an **ileo-caecal valve** which directs the food into the caecum before passing into the colon.

(*viii*) **Caecum.** The caecum is a large thin-walled tube situated at the junction of the small and large intestines. It shows a spiral constriction which indicates the internal presence of a narrow **spiral valve.** The caecum terminates in a narrower, smooth, blind tube, the **vermiform appendix.**

(*ix*) **Large-Intestine.** The large intestine which is about a metre long, shows two regions : the **colon** and the **rectum.** The colon is wider and gives sacculated appearance while the rectum is narrow and gives beaded appearance due to the presence of faecal pellets in it. The rectum includes the proctodaeum and leads to the exterior at the anus.

(*x*) **Anus.** The anus lies at the end of the abdomen under the base of the tail. It is guarded by a sphincter muscle.

2. Digestive Glands. The digestive glands are intimately associated with the alimentary canal. They include the **salivary glands, gastric glands, liver, pancreas** and **intestinal glands.**

(*i*) **Salivary Glands.** The salivary glands occur in two pairs : larger **parotid glands** located below and somewhat anterior to the pinnae and the smaller **sublingual glands** which lie under the tongue. They secrete an alkaline juice, the **saliva**, which is poured into the buccal cavity by fine ducts. The **parotid ducts** open into the vestibule opposite to the upper molar teeth. The **sublingual ducts** open into the beginning of the buccal cavity. The saliva contains an enzyme called **ptyalin.**

(*ii*) **Gastric Glands.** The gastric glands are very numerous in number and microscopic in size. They lie in the mucous membrane lining the stomach. They secrete an acidic juice, the **gastric juice,** which is discharged into the lumen of the stomach. The gastric juice contains hydrochloric acid, a proenzyme called **pepsinogen,** an enzyme **rennin** and mucus.

(*iii*) **Liver.** The liver (Figs. 18.4 and 18.5) is the largest gland in the body. It develops as an outgrowth from the embryonic gut. It is dark-red in colour and fits into the posterior concavity of the diaphragm

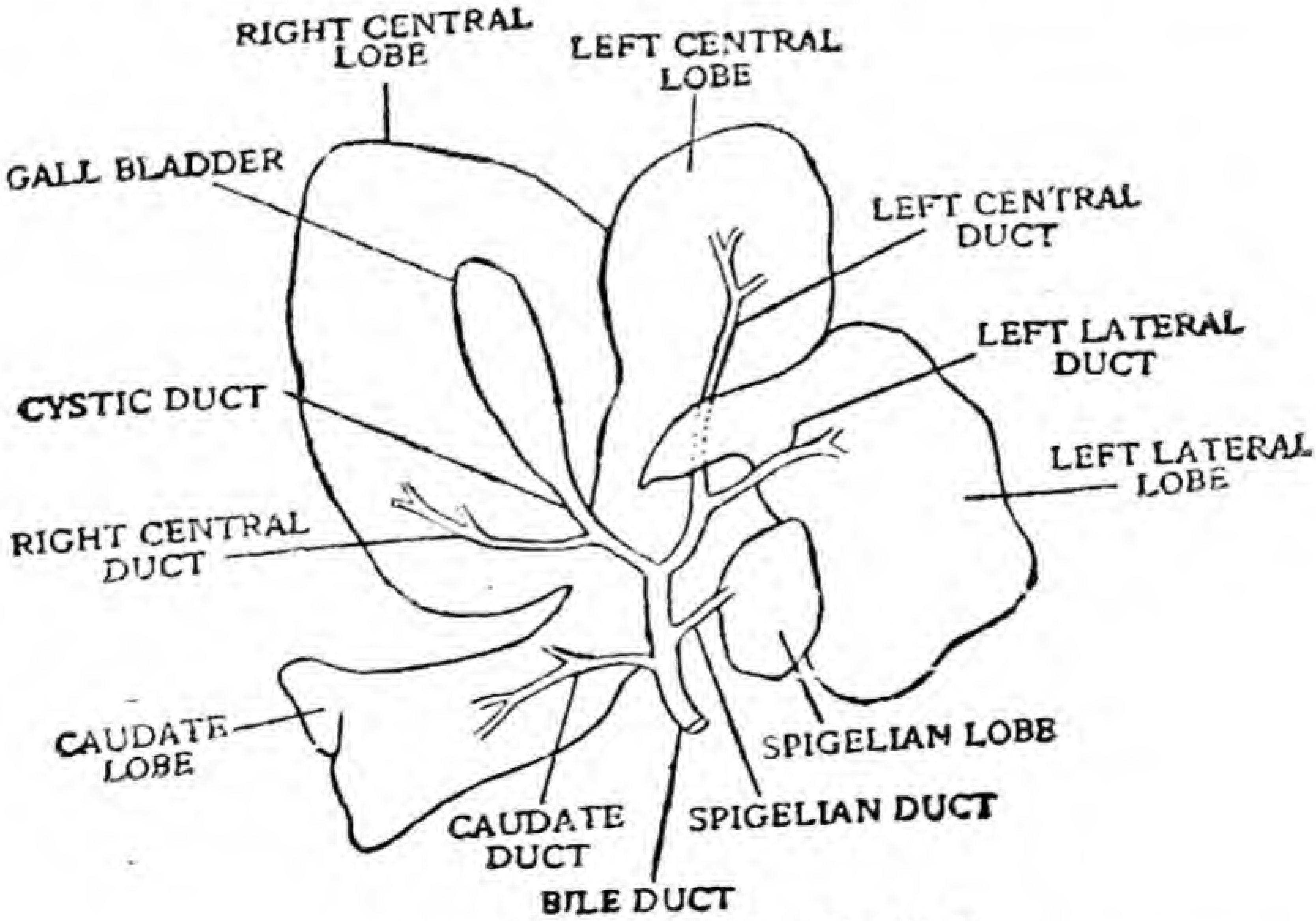


Fig. 18.5. The liver of rabbit

with which it is attached by a fold of peritoneum. It consists of five lobes ; the **right central** or **cystic lobe**, the left **central lobe**, **the left lateral lobe**, the **caudate lobe** and the **spigelian lobe.** A thin-walled elongated sac, the **gall-bladder**, lies embedded in the right central lobe. The gall-bladder stores bile which is secreted by the liver. The bile is greenish in colour and imparts the same colour to the gall-bladder. Bile is carried into the proximal limb of the duodenum by the **common bile-duct** or **ductus choledochus** which is formed by the union of a **cystic duct** from the gall-bladder and several **hepatic ducts** from the lobes of the liver. The opening of the **ductus choledochus** is guarded by a sphincter muscle, the **sphincter of Oddi.**

(*iv*) **Pancreas.** The pancreas is an irregular gland consisting of a number of lobules held in the mesentery between the two limbs of the duodenum. It develops as outgrowths from the embryonic gut. It secretes an alkaline juice, the **pancreatic juice**, which is carried into the distal limb of the duodenum by the **pancreatic duct.** The pancreatic juice contains three enzymes : **trypsin, amylase,** and **lipase,** which act on the proteins, starches, and fats respectively.

(*v*) **Intestinal Glands.** The intestinal glands are again very numerous and microscopic. They lie in the wall of the duodenum and ileum and pour their secretion, the **intestinal juice (succus entericus),** into their lumen. The juice contains many enzymes which act on all types of food.

Besides the glands described above, virtually the entire digestive tract performs glandular function. From mouth to anus, mucus is produced in abundance by specialised epithelial cells. This mucus lubricates the tract, thereby reducing friction between food masses and wall of the tract.

Food

Nature. Rabbit, as indicated earlier, is herbivorous and feeds mainly on grass, cereals and vegetables. All these substances, being living, are composed of protoplasm which is a mixture of several organic and inorganic substances. The organic substances include proteins, starches, fats, sugar and vitamins. The inorganic materials are water and mineral salts of many different kinds. In other words, rabbit's food consists of all these compounds. Of these, the sugars, mineral salts and water have small molecules which readily form a solution and pass from the lumen of the alimentary canal into the blood through the mucous membrane. This process is called **diffusion** and the compounds, the **diffusible foods.** The proteins, starches and fats, on the other hand, have very large molecules which do not form a solution and hence do not pass into the blood. They are called **non-diffusible foods.** They must be rendered diffusible so that the body may make use of them. This is achieved by the action of enzymes in the various parts of the alimentary canal and is called **digestion.** Digestion by enzymes in reality involves hydrolysis in which one or more molecules of water are

chemically united with a larger molecule, thereby splitting the latter into smaller and simpler ones.

Use. Proteins are used in the animal body for growth and repair of tissues as well as for energy. Carbohydrates (starches and sugars) are used for daily energy. Fats provide heat and energy. Water acts as a solvent and is needed in all chemical reactions. Vitamins and minerals regulate the metabolism and often act as catalytic agents.

Physiology of Digestive System

The primary function of the digestive system, as mentioned earlier, is to provide food to the body tissues. This is brought about by several processes.

1. **Ingestion**. Small pieces are cut off from the food plants by means of the chisel-shaped incisor teeth, seized by the movable lips and taken into the buccal cavity through the mouth.

Ingestion of food is controlled by two pairs of centres in the hypothalmus, namely, the **feeding centres** which initiate an urge for eating and the **satiety centres** that direct the animal to stop eating.

2. **Digestion**. Food taken into the alimentary canal **is not truely** inside the body. It will be within the body only **when it is** digested and enters the blood or lymph. Digestion starts **in the buccal** cavity, continues **in** the stomach and is completed in the small **intestine**.

(*a*) **Buccal Cavity**. Here the food undergoes many operations. It is tasted by the taste-buds ; moistened with mucus and saliva for easy chewing ; masticated by the grinding teeth ; starches are hydrolysed or changed into compound sugars, like dextrin and maltose by **ptyalin** of the saliva ; and made into a ball or **bolus** by the working of the tongue against the palate. Finally, the food-bolus is pushed back into the pharynx by pressing the tongue against the hard palate. This is a voluntary process and initiates the act of **swallowing** or **deglutition.**

When the food enters the **pharynx**, the epiglottis closes the glottis and the soft palate rises up to close the internal nares. This prevents the food from going the wrong way. The muscles of the pharynx contract to push the food-bolus into the oesophagus. All this happens **by reflex** action.

(*b*) **Oesophagus**. The oesophagus simply **forces the** food back into the stomach by the contraction of its walls. This also oocurs by reflex action and completes the act of deglutition.

(*c*) **Stomach**. Here the food meets the gastric juice from the gastric glands. The gastric glands are stimulated to secrete their juice by a hormone, the **gastrin**, which is secreted by the mucous membrane of the pyloric stomach and is carried to the glands by the blood stream. Hydrochloric acid of the gastric juice plays many important roles. It disinfects the food by killing bacteria, stops the action of ptyalin, converts the passive pepsinogen of the juice into active pepsin and provides an acid medium to the pepsin for hydrolysing proteins into proteoses and peptones. **The rennin curdles** or **coagulates milk in the**

young animals so that it may remain longer in the stomach to ensure proper action of pepsin. The wall of the stomach undergoes muscular contractions to churn the food. This breaks the food mechanically to some extent and mixes it thoroughly with the gastric juice for proper action of enzymes. Initially, the contractions start in the fundus with the first feeling of hunger and become accelerated both in frequency and extent by the mechanical presence of the ingested food. They cease when the contents attain a suitable acidity. Thus, the hydrochloric acid has yet another role, *i.e.* inhibiting stomach contractions. The acid mixture of the gastric juice and the semidigested food formed in the stomach is called the **chyme.** The latter gradually passes through the pyloric valve into the duodenum by wave-like or peristaltic contractions (to be described later) of the stomach.

(*d*) **Duodenum**. Here the food meets two juices, bile from the liver and pancreatic juice from the pancreas. Both these juices are brought to the duodenum by the hormones produced by the duodenal epithelium, namely, **cholecystokinin**, which forces the gall-bladder to release its bile and **secretin** which activates the pancreas to secrete pancreatic juice. The bile is an alkaline fluid. It contains no digestive enzyme and consequently has no chemical action on food. It, however, neutralizes the acidity of the chyme as it arrives from the stomach and emulsifies fats, *i.e.* breaks up the larger fat droplets into smaller ones for more efficient action of the pancreatic juice. It also serves as an antiseptic to check the growth of bacteria on the chyme. The bile salts also increase the water solubility of fatty acids and substances like vitamin K, necessary for blood clotting. The pancreatic juice is also alkaline. It contains three enzymes : **trypsin, amylase** and **lipase. Trypsin** is secreted in the juice in an inactive form called **trypsinogen**. The latter is activated to trypsin by a substance **enterokinase** produced by the epithelium of the small intestine (duodenum and ileum). Trypsin breaks the proteins, proteoses and peptones into polypeptides ; amylase (amylopsin) converts starches into sugar (maltose) ; and lipase (steapsin) changes the emulsified fats into fatty acids and glycerol.

(*e*) **Ileum**. Here food meets the intestinal juice or succus entericus from the intestinal glands. This juice too is alkaline. It contains many enzymes which complete the process of digestion. The important enzymes are **peptidases** (former erepsin), **lipase, invertase, maltase** and **lactase**. Peptidases convert polypeptides into amino-acids. Lipase changes the remaining fats into fatty acids and glycerol. Invertase breaks sucrose into glucose and fructose. Maltase transforms maltose into glucose. Lactase converts lactose into glucose. The fluid food formed in the ileum by the action of enzymes on the chyme is called **the chyle.**

(*f*) **Caecum.** Here the food undergoes partial digestion by the activity of micro-organisms like certain bacteria and protozoans. The cellulose part of the rabbit's food escapes the action of the enzymes. It is broken by micro-organisms of the caecum into simpler but still indigestible form. The simplified cellulose escapes with the faeces.

This association between the rabbit and the micro-organisms is beneficial to both the partners. It is, therefore, known as **symbiosis** and the partners as **symbionts**.

3. **Absorption.** Absorption of food mainly occurs in the **ileum**. For this purpose, the surface area of the ileum is enormously increased by the development of innumerable finger-like projections, the **villi**, from its inner surface. Each villus has abundant blood-capillaries and one large lymph vessel, the **lacteal**. The digestion products of carbohydrates and proteins, namely, glucose and amino-acids, are absorbed into the blood capillaries of the villi and are carried to the liver by the hepatic portal vein. From here they finally get into the blood circulation. The digestion products of the fats, namely, fatty acids and glycerol, are absorbed into the lacteals of the villi and are readily synthesized into fat globules. From the lacteals the fat globules are carried into the blood circulation by lymphatic system without going round the liver.

4. **Assimilation of food**. The food materials absorbed by the blood from the alimentary canal are distributed to all the cells of the body during its circulation. In side the cells the food materials are changed into starches and proteins under the influence of certain intracellular enzymes. The proteins are further transformed into protoplasm while the fats and starches are largely used as sources of energy.

5. **Egestion.** Egestion of food is carried out by the large intestine. The chyle entering the large intestine consists of 75—80 per cent water and several fatty and proteinaceous substances, including excess enzymes. In the colon, water is absorbed into the blood, thus concentrating the chyle into faeces. The faeces collect in the **rectum** as small pellets which become hard by further absorption of water from them. At intervals, the faecal pellets are thrown out through the anus whose sphincter muscle relaxes for this purpose.

Besides conservation of water, the colon performs a few other functions also. Its bacterial symbionts feed on the protein content of the chyle, breaking them into simpler substances, some of which are absorbed into the blood. During their metabolic activities, the bacteria produce a few vitamins which are also absorbed. Moreover, the wall of the colon absorbs some inorganic substances (like salts of calcium, magnesium, iron and copper) from the blood and deposits them into the cavity for elimination with the faeces.

Coprophagy or Refection

The faeces passed out by the rabbit at night is moist and soft and contains simplified cellulose. It is eaten up by the rabbit and passed through the gut once more for the digestion and absorption of the simplified cellulose. This habit of passing the food twice through the alimentary canal ensures maximum amount of nutriment from it and is called **coprophagy** or **refection**. The faeces thrown by rabbit at night also contains some vitamins which are produced by bacterial action in the large intestine.

Protection of Intestinal Mucosa

The delicate epithelial lining of the alimentary canal is not affected by the digestive enzymes because it is coated with mucus which minimises the action of enzymes, it secretes anti-enzymes which prevent the action of enzymes and lastly the enzymes, particularly the proteolytic ones, are secreted in an inactive form.

Movements of Alimentary Canal

The alimentary canal performs three types of movements: **peristaltic, segmenting** and **pendular.**

1. **Peristaltic Movements.** The peristaltic movements consist of waves of contraction that continuously pass over the wall of the gut from the anterior to the posterior end, gradually pushing the food backwards (Fig. 18.6.)

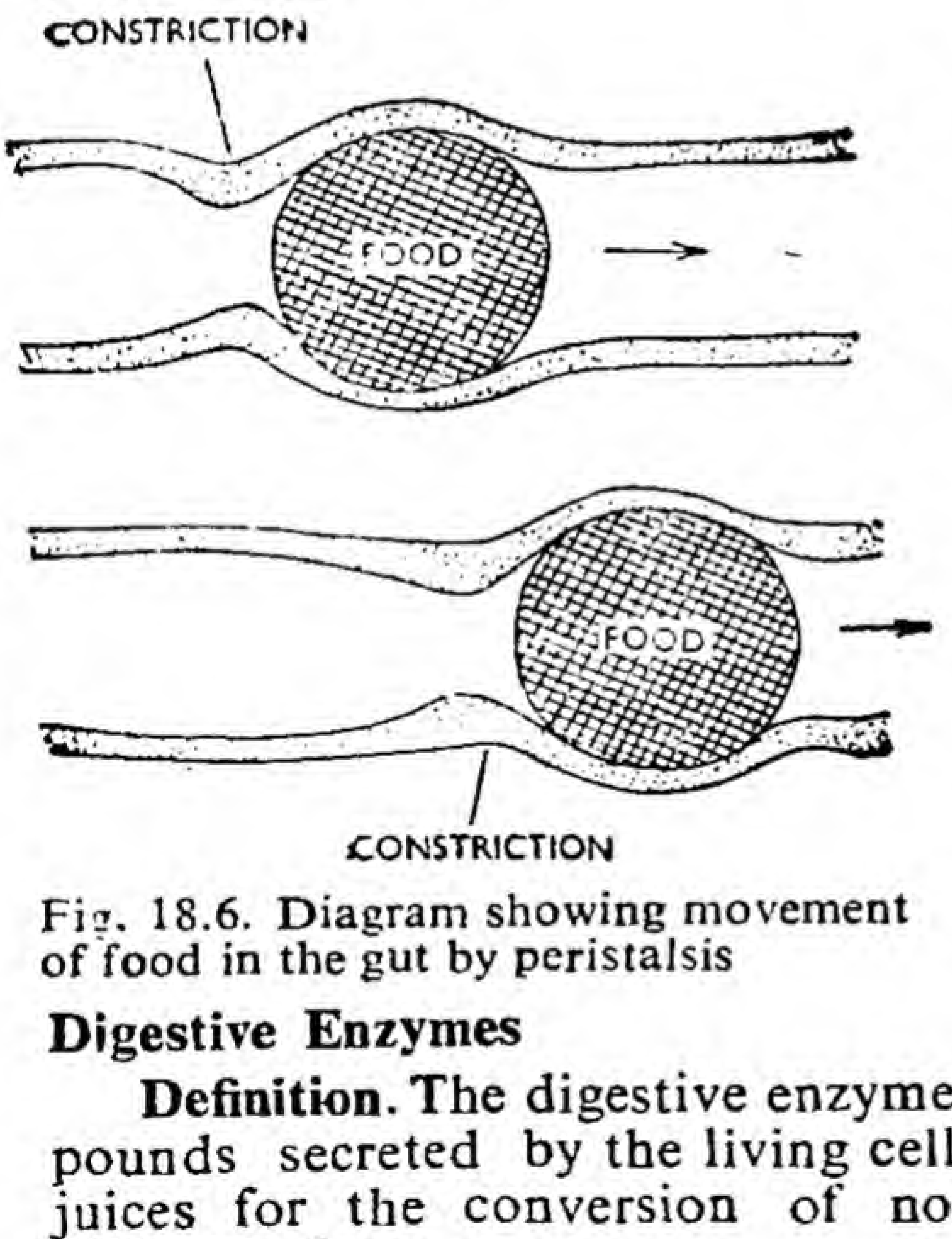


Fig. 18.6. Diagram showing movement of food in the gut by peristalsis

2. **Segmenting Movements.** The segmenting movements consist of a series of regularly-spaced ring-like constrictions dividing the gut into a series of segments. These constrictions soon disappear and new ones appear alternating with them. These movements serve to mix the food with the juices.

3. **Pendular Movements.** These movements consist of ring-like contractions that pass forwards and backwards over short lengths of intestine and cause loops of intestine sway slowly in a pendular manner. They serve to churn and mix the contents.

Digestive Enzymes

Definition. The digestive enzymes or **ferments** are the organic compounds secreted by the living cells of the digestive glands in their juices for the conversion of nondiffusible food substances into the diffusible form.

Properties. The digestive enzymes possess almost all the properties of the catalytic agents and are often referred to as the **organic catalysts or biocatalysts.** Like catalytic agents, the enzymes bring about a chemical change in the nature of the food without undergoing any change themselves. They are very sensitive to temperature, working best at 30 to 45°*C* They are destroyed at too low or too high temperatures. They are specific in reaction, *i.e.* one enzyme can act only on one kind of food. They function in a specific medium, some in alkaline, others in acidic. Finally, they are required in very small doses.

Classification. Three categories of digestive enzymes are recognized on the basis of the type of food on which they act. These are called the **proteolytic, amylolytic** and **lipolytic** enzymes.

TABLE 9

SUMMARY OF ENZYME ACTIVITIES IN THE DIGESTIVE TRACT

Region	Gland	Juice	Nature	Enzyme	Acts on	End product	Other functions of the Juice
1. Buccal cavity	Salivary Glands	Saliva	Slightly alkaline	Ptyalin	Starch	Maltose Dextrin	1. Moistens food for easy mastication and swallowing.
2. Stomach	Gastric Glands	Gastric Juice	Acidic	(*i*) Pepsin Secreted as a proenzyme pepsinogen which is activated to pepsin by HCl	Proteins	Proteoses and peptones	1. Disinfects the food with HCl. 2. Stops the action of ptyalin. 3. Dissolves the salts like calcium carbonates. 4. Forms the acidic medium for pepsin.
				(*ii*) Rennin	Milk	Curd	
3. Duodenum	Liver	Bile	Alkaline	×	Fats	Emulsion	1. Acts as an antiseptic to check the growth of bacteria on food. 2. Neutralizes the effect of HCl and accelerates the action of pancreatic juice.
	Pancreas	Pancreatic Juice	Alkaline	(*i*) Trypsin Secreted as proenzyme trypsinogen that is activated to trypsin by enterokinase.	Proteins, proteoses and Peptones	Polypeptides	1. Neutralizes the HCl.
				(*ii*) Amylase	Strach	Maltose	
				(*iii*) Lipase	Fats	Fatty Acids & Glycerol	
4. Ileum	Intestinal glands	Intestinal Juice (succus entericus)	Alkaline	(*i*) Peptidases	Polypeptides	Amino-Acids	1. Mucous membrane of the ileum secretes certain substances which increase the flow of bile, pancreatic juice and intestinal juice.
				(*ii*) Lipase	Fats	Fatty Acids and Glycerol	
				(*iii*) Invertase	Sucrose	Glucose and Fructose	
				(*iv*) Maltase	Maltose	Glucose	2. They also inhabit the secretion of gastric juice.
				(*v*) Lactase	Lactose	Glucose	

The **proteolytic enzymes** act on proteins and break them into amino-acids, *e.g.* pepsin of the gastric juice, trypsin of the pancreatic juice and peptidases of the intestinal juice.

The **amylolytic enzymes** convert starches into sugars, *e.g.* ptyalin of the saliva and amylase of the pancreatic juice.

The **lipolytic enzymes** split fats into fatty acids and glycerol, *e.g.* lipase of the pancreatic and intéstinal juices.

Liver

The liver is much more than a mere digestive gland. It, therefore, deserves a separate mention. Its position, form and structure have already been discussed in the digestive glands. It perform the following functions :—

1. It secretes bile which emulsifies fats, prevents putrefaction of food by checking the growth of bacteria and neutralizes the acid coming from the stomach.

2. It separates the excess of sugars from the blood and stores it in its cells as glycogen (animal starch). This takes place when the animal gets plenty of food. During the days of food scarcity, the stored glycogen is rendered diffusible by certain enzymes and restored to the blood stream for distribution to the body.

3. While acting as a storage organ for glycogen, the liver goes a long way in maintaining a fixed percentage of sugar in the blood.

4. In the liver, the excess amino-acids change into ammonia. Being highly toxic, ammonia is immediately changed into urea. The urea enters the blood and is carried to the kidneys, where it is excreted in the urine.

5. The liver collects the haemoglobin of the worn out red corpuscles and passes it into the alimentary canal along with the bile for elimination in the faeces.

6. The liver produces heparin and fibrinogen. The former prevents the clotting of blood inside the blood-vessels and the latter helps in the clotting of blood which oozes out from the injured blood-vessels.

7. The liver produces red blood-corpuscles in the embryo.

8. Finally, the liver generates heat.

TEST QUESTIONS

1. Give an account of the alimentary canal and digestive glands of rabbit.
2. Describe the journey of food through the alimentary canal of rabbit.
3. Write brief notes on—

Teeth of rabbit, Liver, Peristalsis, Enzymes and Protection of Intestinal Mucosa.

4. What is the function of the digestive system ? Explain the following processes, giving the place of occurrence of each :—

Digestion, Absorption, Assimilation, Emulsification, and Egestion.

5. Name the various constituents of the food of rabbit and describe the changes they undergo in the various regions of the gut.

CHAPTER 19

Oryctolagus cuniculus

(The Rabbit)

RESPIRATORY SYSTEM AND SOUND-PRODUCING ORGANS

The respiratory and sound-producing organs are closely linked up. In fact, a small specialised part of the respiratory system functions as the voice-box. This is why the two are studied together.

RESPIRATORY SYSTEM

One of the functions of food supplied to the cells of the body by digestive system is to act as fuel and provide energy for metabolic activities. The energy is released by oxidation or burning of food inside the cells. During oxidation, oxygen is used and carbon dioxide is produced as a waste material along with the liberation of energy. This is similar to the burning of coal in the presence of oxygen to yield heat and carbon dioxide ($C+O_2 \longrightarrow CO_2+$heat). To keep the oxidation going on, there is, thus, a constant need for the supply of oxygen to the cells and for the elimination of carbon dioxide from them. This is done by the respiratory system.

A. Morphology of Respiratory System

The respiratory system may be subdivided into two parts : a conducting part called the **respiratory tract** and an essential part called the respiratory organs. The respiratory tract serves as a pathway for the air to and from the respiratory organs where the actual oxygenation of the blood occurs.

1. **Respiratory Tract.** The respiratory tract conveys fresh air from the exterior to the respiratory organs and returns the foul air. It includes the external nares, nasal chambers, internal naris, pharynx, larynx, trachea, bronchi and bronchioles (Figs. 18.1 and 19.2).

(*i*) **External Nares.** The external nares are a pair of oval slits obliquely placed under the fleshy tip of the snout. They communicate with the mouth by a vertical cleft in upper lip. They lead into the nasal chambers.

(*ii*) **Nasal Chambers.** The nasal chambers are a pair of long passages above the palate. The two chambers are separated from each other by a median vertical partition. They are divisible into three regions : anterior **vestibular**, middle **respiratory** and posterior **olfactory**. The

a shell shaped st.

vestibular region is just within the external nares. It is lined with skin (stratified squamous epithelium) and bears hair and sebaceous glands. The hair act as a sieve. The respiratory and olfactory regions form the greater part of each nasal chamber. They have three thin plates, **conchae**. The latter are scroll-like projections of the nasal, maxillary and ethmoid bones and are called the **superior, ventral** and **lateral nasal conchae** respectively. The conchae immensely increase the surface of the nasal chambers. The respiratory region is lined with **respiratory epithelium** which is a highly vascular ciliated columnar epithelium rich in mucous cells. This region acts as an air conditioner. The olfactory region is lined with olfactory epithelium (Fig. 22.3) for the sense of smell. The nasal chambers open behind into the pharynx by a common aperture, the internal naris.

(*iii*) **Internal Naris**.—The internal naris is bounded ventrally by the posterior free semicircular edge of the soft palate called the **uvula**. The latter rises up during the act of swallowing food to close the internal naris.

(*iv*) **Pharynx**. The pharynx is a common passage for the food and air which cross each other here. Its upper part that receives the internal naris is called the **nasopharynx** while its lower part lying directly behind the buccal cavity is termed the **oropharynx**. There is no demarcation between the two regions of the pharynx. The pharynx is lined with ciliated epithelium. At the hind end of the pharynx lies a slit-like aperture, the **glottis**. The latter bears at its anterior edge a cartilaginous flap, the **epiglottis**. The epiglottis closes the glottis during swallowing of food. The glottis leads into the larynx.

(*v*) **Larynx**. The larynx is a short tubular chamber strengthened by cartilaginous framework. It serves as the voice box and will be described in the sound-producing organs. It is lined with ciliated epithelium whose cilia beat towards the pharynx. It is followed by trachea.

(*vi*) **Trachea**. The trachea is a thin-walled tube. It passes backwards through the neck beneath the oesophagus. On entering the thorax, it divides into two branches, the **primary bronchi**, which enter the corresponding lungs. Inside the lungs, the primary bronchi divide and subdivide into secondary and **tertiary bronchi**. The latter further divide to form very fine tubules, the **bronchioles**. The wall of the trachea and bronchi is composed of fibrous and muscular tissue. It is supported by rings of cartilage, incomplete dorsally, to prevent them from collapsing. The supporting rings, however, become thinner posteriorly and finally disappear altogether over the bronchioles. The trachea, bronchi and bronchioles are lined by ciliated columnar epithelium containing numerous mucus-secreting cells. The mucus helps in holding the dust and bacteria which are swept towards the pharynx by cilia.

2. **Respiratory Organs**. The respiratory organs are a pair of lungs situated in the thoracic cavity on the sides of the heart. The thoracic cavity is an air-tight chamber enclosed laterally, dorsally and ventrally by the ribs, thoracic vertebrae and sternum together with the muscles

in which these bones are embedded. Posteriorly, the thoracic cavity is walled by the diaphragm which is convex anteriorly. The root of the neck forms the anterior boundary of this cavity (Fig. 15.3). Each lung is enclosed in two membranes, the **pleura**, which in reality are the layers of coelomic epithelium or peritoneum of the thorax. The inner

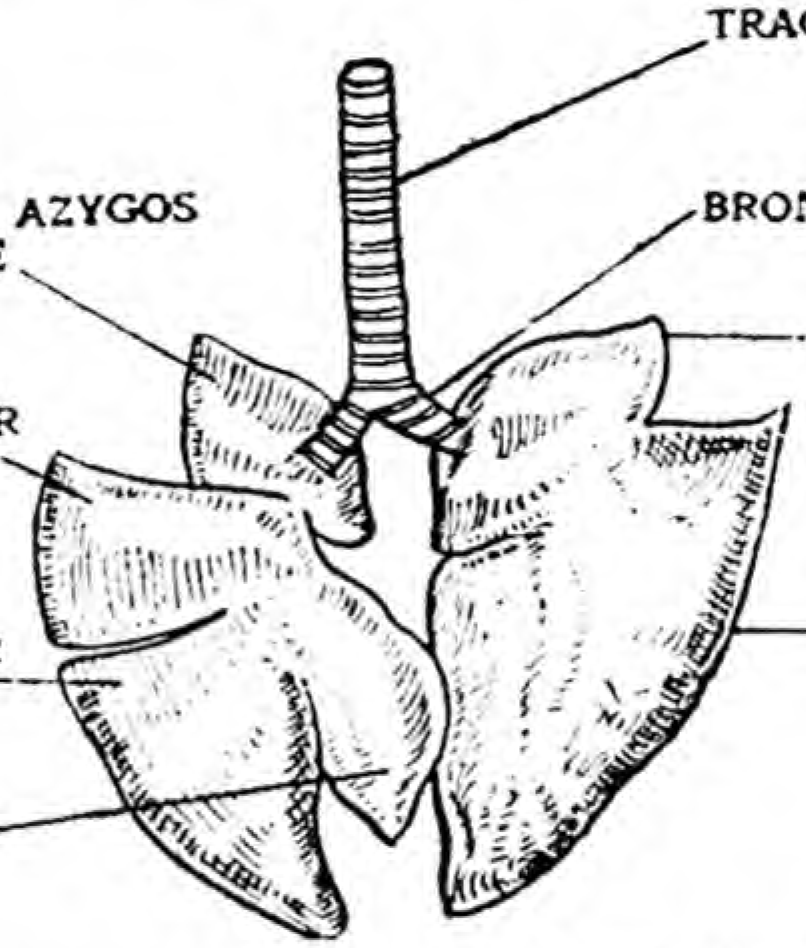


Fig. 19.1. The trachea and lungs of rabbit (ventral view)

one, called the **visceral pleuron**, closely invests the lungs while the other, called **parietal pleuron**, lines the thoracic cavity. The two pleura are continuous with each other over the bronchi (Fig. 15.1). During life the lungs are fully expanded to fill up the thoracic cavity so that the two pleura lie close to each other. The space between the two, called the **pleural cavity**, contains a watery fluid which permits them to glide over one another in the respiratory movements.

The lungs (Fig. 19.1) are soft, spongy and elastic organs of pinkish colour. They are divided by clefts into lobes. The left lung consists of two lobes : the **left anterior** and the **left posterior lobes**. The right lung has four lobes : **the anterior azygos**, the **right anterior**, the **right posterior** and the **posterior azygos lobes**. Inside the lung, each ultimate bronchiole splits up into a few branches, the **alveolar ducts**, of smaller diameter. Each alveolar duct ends in a blind chamber, the **alveolar sac** or **infundibulum**. The latter consists of a central passage giving off numerous small pouch-like projections, the **alveoli** or **air-sacs**. The very thin wall of the alveoli is composed of squamous epithelium and is closely surrounded by a network of capillaries (Fig. 19.2). The blood in the capillaries is, therefore, separated from the air in the alveoli by just two layers of cells, *i.e.* capillary endothelium and alveolar epithelium. With the result, the diffusion of gases from the blood to alveolar air and vice versa can occur easily and quickly.

Each alveolus is, thus, a miniature lung. A group of infundibula supplied by alveolar ducts from a single bronchiole is termed a **lobule of the lung**. Each lung has innumerable such lobules and this makes the **lungs spongy**.

B. Physiology of Respiratory System

The respiratory system, as stated earlier, provides oxygen to the cells of the body and removes carbon dioxide from them. This process is called **respiration.** It occurs in two phases. In the first phase, the blood takes up oxygen from the fresh air taken into the lungs and adds its carbon dioxide to it. This phase is called the **external respiration or breathing** or **ventilation**. In the second phase, the blood distributes

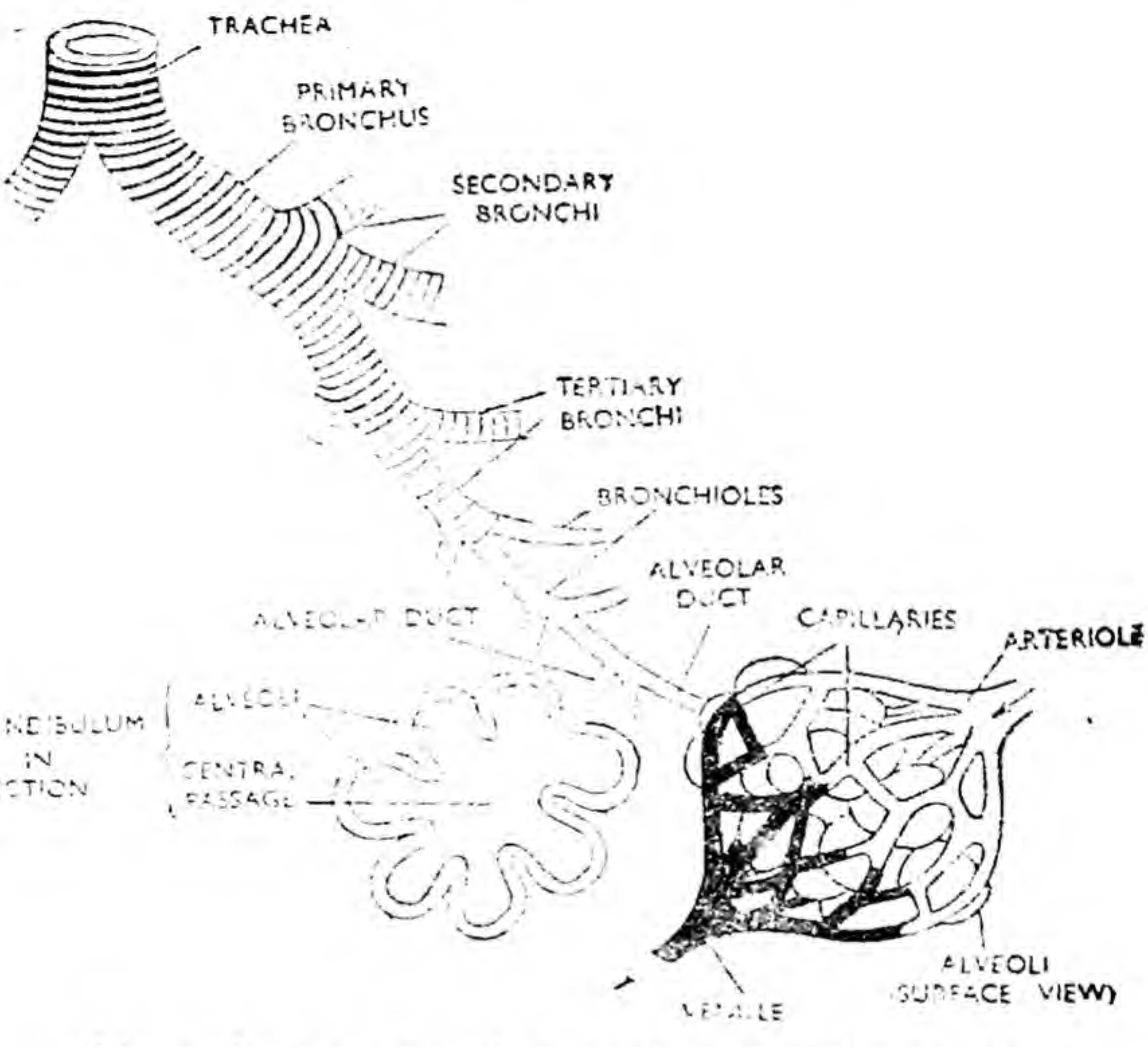


Fig. 19.2. Branches of the trachea and infundibula

oxygen to the cells of the body and collects carbon dioxide from them. This phase is termed the **internal** or **tissue respiration.** Blood, thus, plays a vital role in respiration. It carries oxygen from the lungs to the cells and carbon dioxide from the latter to the former.

(*a*) **Inspiration** (Fig. 19.3). The muscles of the diaphragm contract and make it almost flat. This enlarges the thoracic cavity antero-posteriorly. The external intercostal muscles of the thorax also contract and pull the ribs outwards and forwards. This enlarges the thoracic cavity laterally and dorso-ventrally. Increase in the dimensions of the thoracic cavity results in decrease of pressure in the pleural cavities. The negative pressure, thus, caused in the pleural cavities brings about expansion of the lungs. This reduces the pressure of air in the lungs below atmospheric pressure. Since air moves from a place of higher pressure to a place of lower pressure, the fresh air from outside

immediately rushes into the lungs through the respiratory passage till the pressure of air in the lungs becomes equal to that of the atmosphere. On reaching the lungs, the fresh air is distributed by the bronchi, bronchioles and alveolar ducts to the alveoli.

While the fresh air passes through the nasal chambers, it is warmed, moistened, sterilized and cleaned of dust particles. The blood-vessels of the turbinals radiate heat like the hot water pipes and warm the air passing over them. The mucus secreted by the mucous glands of the turbinals is gradually evaporated to moisten the passing air. The mucus is sticky and antiseptic. It holds and kills the bacteria of the air. The cilia of the nasal chambers by their ceaseless beating "sweep" the foreign particles (dust and germs) trapped in the sticky mucus to the exterior via external nares. All this indicates the advantages of nasal breathing over mouth breathing.

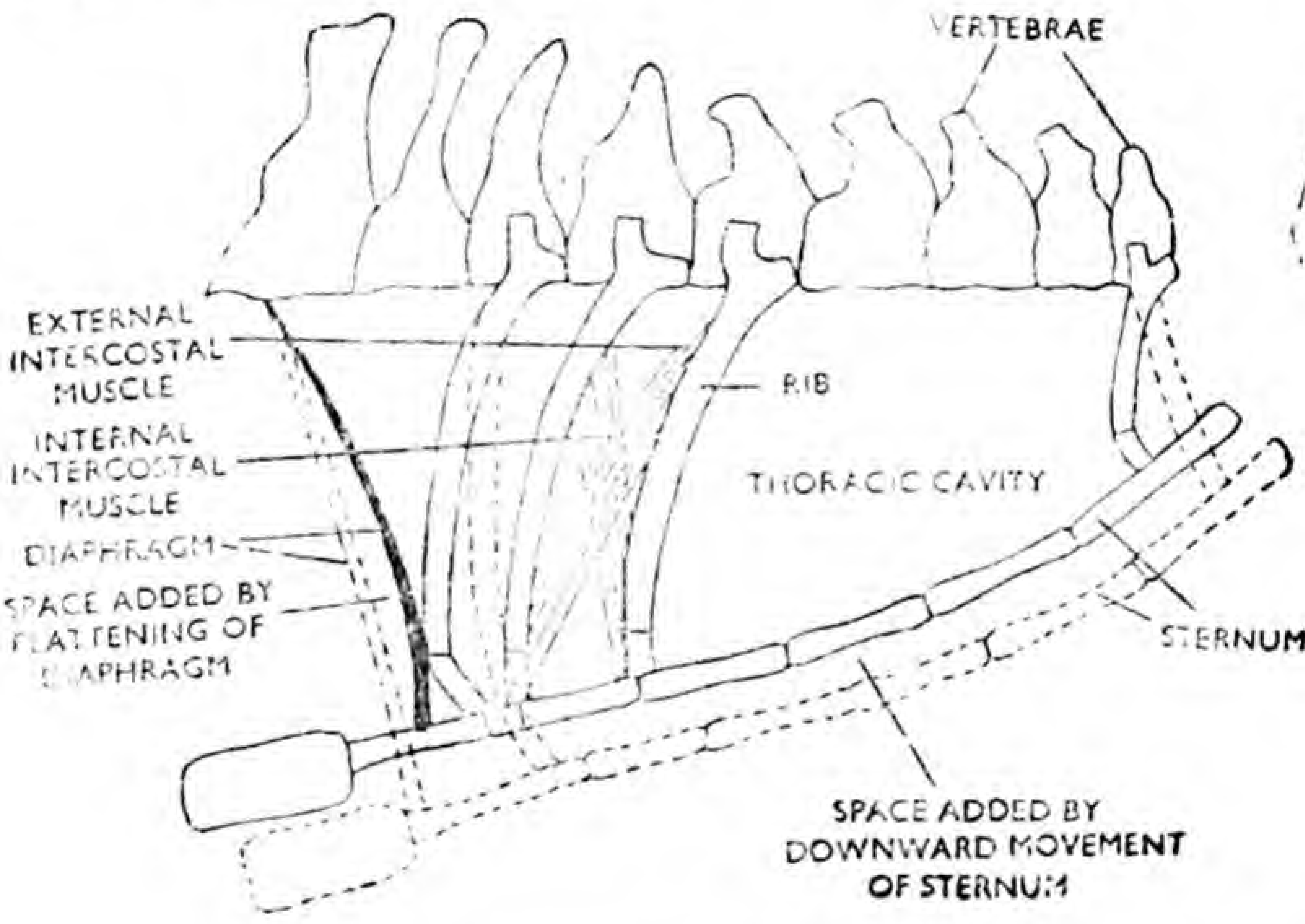


Fig. 19.3. Mechanism of breathing.
Solid lines show the position of ribs, sternum and diaphragm during normal position and dotted lines during inspiration

The cilia lining the trachea and bronchi also clean the air by sweeping the tiny foreign particles towards the pharynx where they are disposed off by swallowing.

The air in the alveoli has a higher concentration of oxygen and a lower concentration of carbon dioxide than the blood flowing in the capillaries wrapped round the alveoli. This difference in the concentration of gases causes their **diffusion** through the walls of the alveoli and capillaries. Oxygen from the alveoli dissolves in the mucus covering their inner surface and passes into the blood while the carbon dioxide passes from the blood into the alveoli. The air of the alveoli, thus, becomes foul and needs renewal.

(*b*) **Expiration**. The reverse of inspiration occurs in expiration.

The muscles of the diaphragm relax and the abdominal viscera, which were compressed momentarily during the flattening of diaphragm, push diaphragm forwards and make it convex anteriorly. The external intercostal muscles relax and the internal intercostal muscles contract. This brings the ribs to their original position. With the result, the thoracic cavity decreases in all dimensions. Decrease in the thoracic cavity raises the pressure in the pleural cavities. The lungs, therfore, contract by virtue of their elasticity. The air in the lungs is, thus, compressed and its pressure rises above atmospheric pressure. Because of its higher pressure, the foul air of the lungs goes out and the air pressure in the lungs falls to that of the atmosphere. On its return journey, the air again passes through the respiratory passage.

By expiration, the lungs never become completely empty. Some air always remains in them as the residual air.

Mechanism of Internal Respiration. The oxygen which diffuses into the blood combines with the **haemoglobin** of the red corpuscles to form a bright red compound, the **oxyhaemoglobin.** The blood with oxyhaemoglobin returns to the heart and is distributed to the cells of the body. The cells have less oxygen than the blood so that an oxygen gradient is set up between the blood and the cells via the lymph or tissue fluid. Oxyhaemoglobin gives up its oxygen and changes into the purple-red haemoglobin. This oxygen diffuses towards the cells where it is used in the oxidation of food. Oxidation is a multistage reaction and occurs under the influence of a variety of enzymes. It ultimately produces carbon dioxide and water and releases energy. Production of carbon dioxide increases its concentration in the cells so that it starts diffusing into the blood. Carbon dioxide travels in the blood partly in the red corpuscles and partly in the plasma. The blood with its load of carbon dioxide returns to the heart which sends it to the lungs where external respiration starts again.

Control of Breathing

Respiration is controlled by two areas, called **respiratory centres,** located near the middle of medulla oblongata. The anterior centre regulates expiration and the other, inspiration. These centres are affected by carbon dioxide level of the blood. Increased concentration of carbon dioxide in the blood stream stimulates the respiratory centres which respond by causing more frequent contractions of the breathing muscles. This accelerates the rate of breathing. Decrease in the amount of carbon dioxide, on the other hand, slows down the rate of breathing.

SOUND PRODUCING ORGANS

The anterior part of the trachea, as mentioned earlier, is modified for the production of sound. It is known as the **larynx** or **voice-box** (Figs. 19.4 and 19.5). Its wall is supported by four cartilages. A broad **thyroid cartilage** supports it ventrally and laterally. A pair of small **arytenoid cartilages** lie in its dorsal wall. Each arytenoid cartilage bears

at its anterior end a small nodule-like **cartilage of Santorini.** A ring-like **cricoid cartilage** surrounds the larynx behind the thyroid and arytenoid cartilages. It is comparatively broad on the dorsal than on the ventral side. Stretching dorso-ventrally across the cavity of the larynx are two pairs of band-like folds, the **false vocal cords** in front and the **true vocal cords** behind. They are formed of yellow elastic tissue covered by mucous membrane of stratified squamous epithelium. The vocal cords are attached to the arytenoid cartilages above and to the thyroid cartilage below and on the sides. The vocal cords enclose the glottis which is a slit between their free edges. The glottis, as mentioned earlier, puts the larynx in communication with the pharynx in front. A

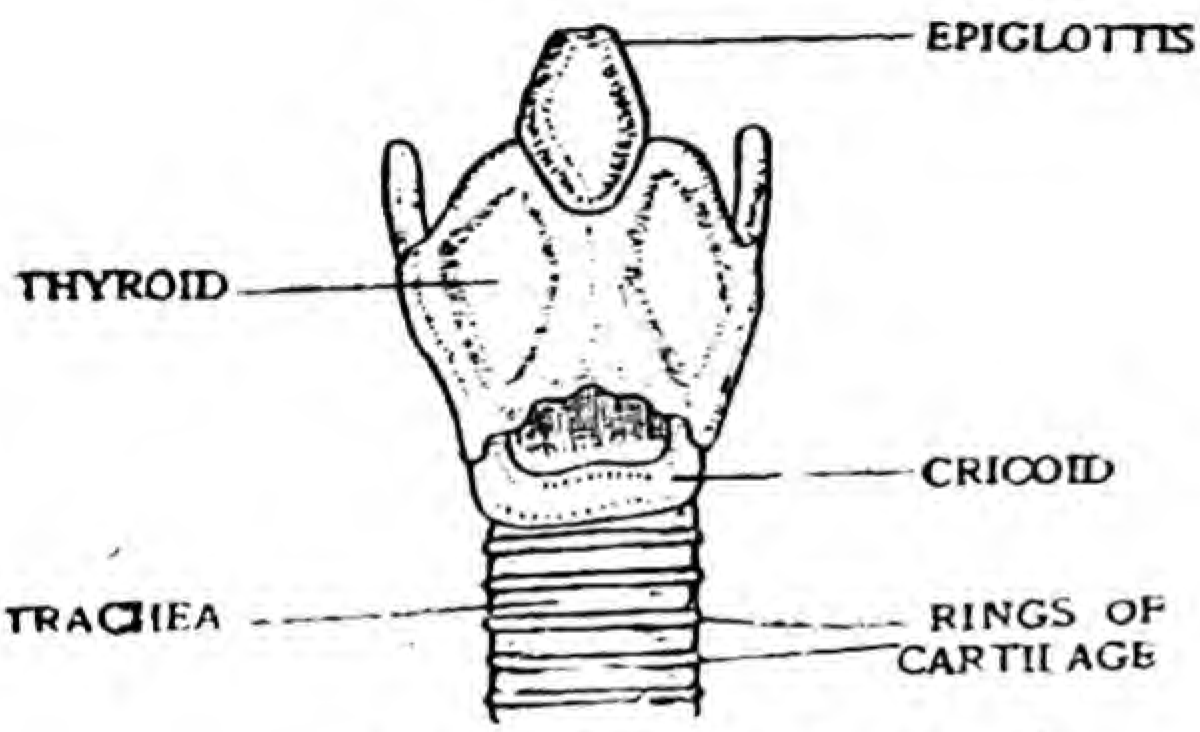


Fig. 19.4. The larynx of rabbit—ventral view

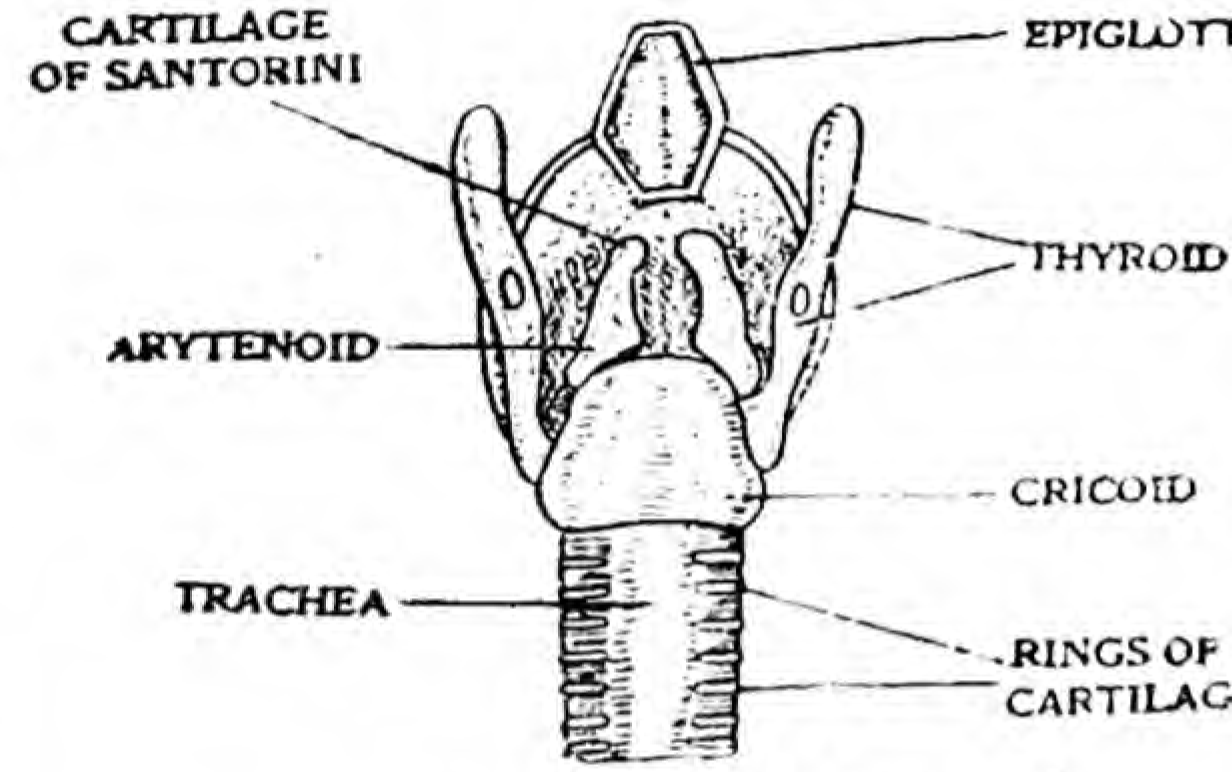


Fig. 19.5. The larynx of rabbit—dorsal view

flap of elastic cartilage, called the **epiglottis,** extends upwards from the anteromedian border of the thyroid cartilage. During swallowing, the epiglottis stands erect and the larynx is moved forwards so that glottis gets closed by the epiglottis and the root of the tongue.

Sound is produced by the vocal cords. When not in use, the vocal cords lie at an acute angle to one another so that the glottis is a wide gap. For the production of sound, they are brought parallel and closer to one another by the action of the laryngeal muscles. Now they are set into vibration by a current of air passed through them under pressure from the lungs. This results in the production of sound. The quality of the sound is altered by variation in the tension of the vocal cords. The rabbit is mainly a silent animal and its sound is merely a squeak.

TEST QUESTIONS

1. Define respiration. Describe the respiratory system of rabbit.
2. Differentiate between the external and internal respiration. Discuss the importance of respiration.
3. Write brief notes on the following—Epiglottis, Pleura, Diaphragm, Haemoglobin, Nasal chambers.
4. Give an account of the sound-producing organ of rabbit. How is the sound produced ?
5. Describe the lungs of rabbit.

CHAPTER 20

Oryctolagus cuniculus

(The Rabbit)

CIRCULATORY SYSTEM

The circulatory system serves to transport materials like food, gases, wastes and hormones. It also defends the body from foreign germs, rids it of worn-out cells, keeps its organs moist and equalises its temperature. All these functions are performed by a fluid tissue, the **blood**. The blood with its load of materials and protective and cleansing agents flows in closed tubes, the **blood vessels**. The blood is kept flowing in the vessels by a muscular pump, the **heart**. The blood starts from the heart and after going round the body comes back to the heart, performing its multifarious duties on the way. This circulation of blood in the body continues without any interruption till the death of the animal.

I. Heart

(*a*) **Shape and Position**. The heart is a hollow, muscular, conical organ of reddish colour. It is situated in the thoracic cavity, occupying its middle part, *i.e.* **mediastinum**, between the two pleural sacs that enclose the lungs (Fig. 15.1). It lies a bit obliquely near the ventral side. Its broad **base** faces forwards and slightly upwards while the pointed **apex** is directed backwards, downwards and slightly to the left side.

(*b*) **Pericardium**. The heart is enclosed in a delicate, transparent, two-layered sac, the **pericardium**. The inner layer, called the **visceral pericardium**, is closely adhered to the heart and the roots of great vessels entering and leaving the heart. From the roots of the great vessels, the visceral pericardium is reflected again round the heart as the outer layer or **parietal pericardium**. The narrow space between the two layers is known as the **pericardial cavity**. It contains a small amount of watery fluid, the **pericardial fluid**. The latter protects the heart from shocks and mechanical injury and allows it free movement. The pericardium is attached to the ventral thoracic wall and diaphragm to keep the heart in position.

(*c*) **External Structure**. The surface of the heart is marked by two faint grooves (Fig. 20.1). One groove runs transversely round the heart and divides it into the anterior small **auricular part** and the posterior large **ventricular part**. The groove is called the **auriculo-ventricular groove**. The other groove runs from the base of the heart obliquely backwards and to the right. It divides the ventricular part into right

and left ventricles and is called the **interventricular groove.** The great blood-vessels are attached at the anterior end of the heart.

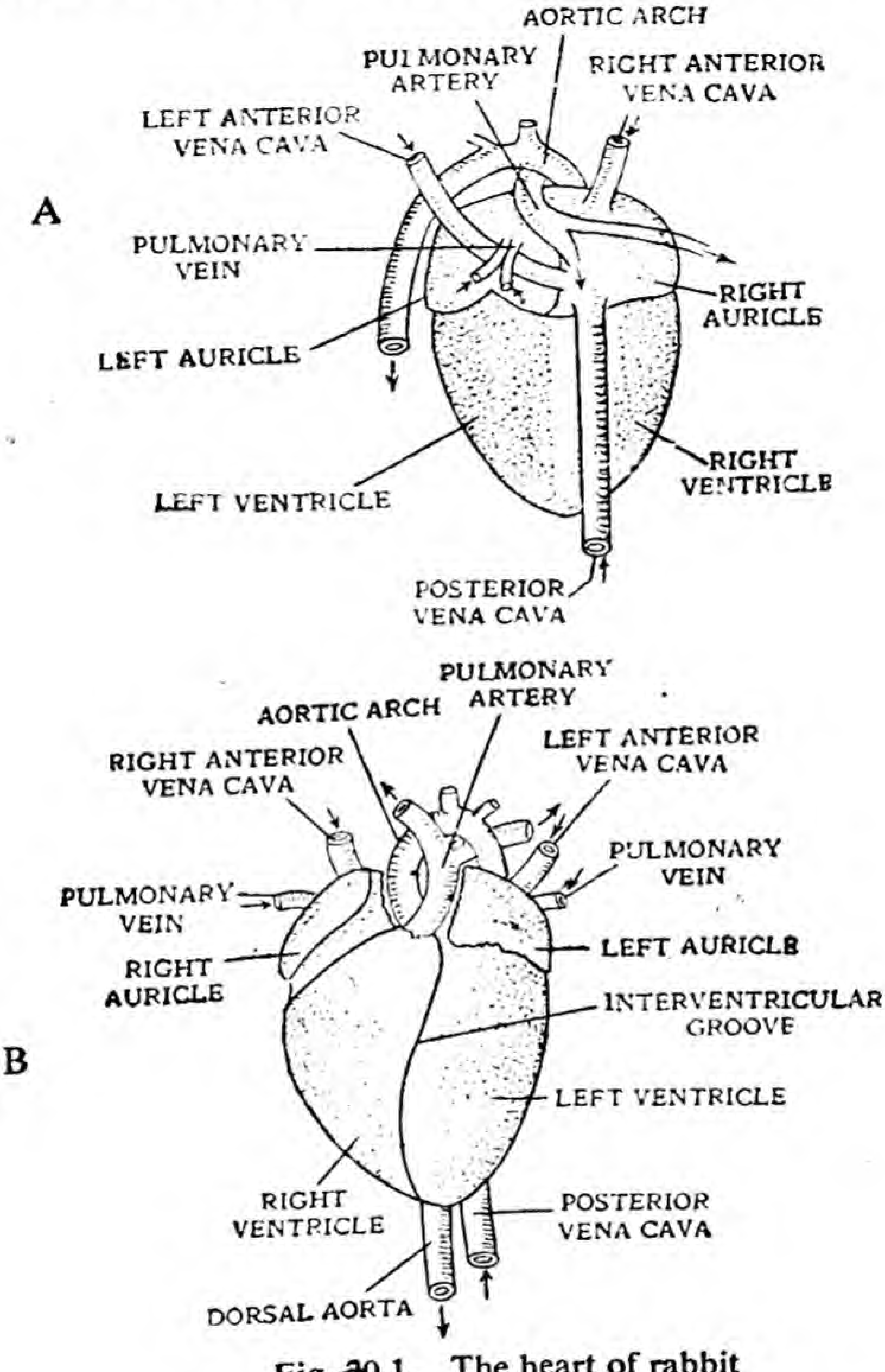


Fig. 20.1. The heart of rabbit
A—Dorsal view B—Ventral view

(*a*) **Internal Structure.** Internally the heart (Fig. 20.2) is divided into two halves : the right and the left, which do not communicate with each other. Each half further consists of two **chambers** : the anterior receiving chamber called the **auricle** or **atrium** and the posterior distributing chamber termed the **ventricle**. The heart of rabbit is, thus, four-chambered.

The auricles have thin walls because they are only to force the blood into the ventricles. Each auricle is produced into a small flap, the **auricular appendix**, which overhangs the base of the corresponding

ventricle. The inner surface of the auricles is smooth except for a network of low ridges, the **musculi pectinati,** in the region of the auricular appendages. The two auricles are separated from each other by an **interauricular septum**. The latter has a small, oval, depressed area, the **fossa ovalis,** which in the embryo has an aperture, the **foramen ovale.**

The ventricles have thicker walls which are much more so in the case of the left ventricle than in the right ventricle. This is because the former is required to pump the blood to the farthest end of the body while the latter only up to the lungs which lie nearby. The inner surface of the ventricles is raised into a network of low ridges called the **colum-**

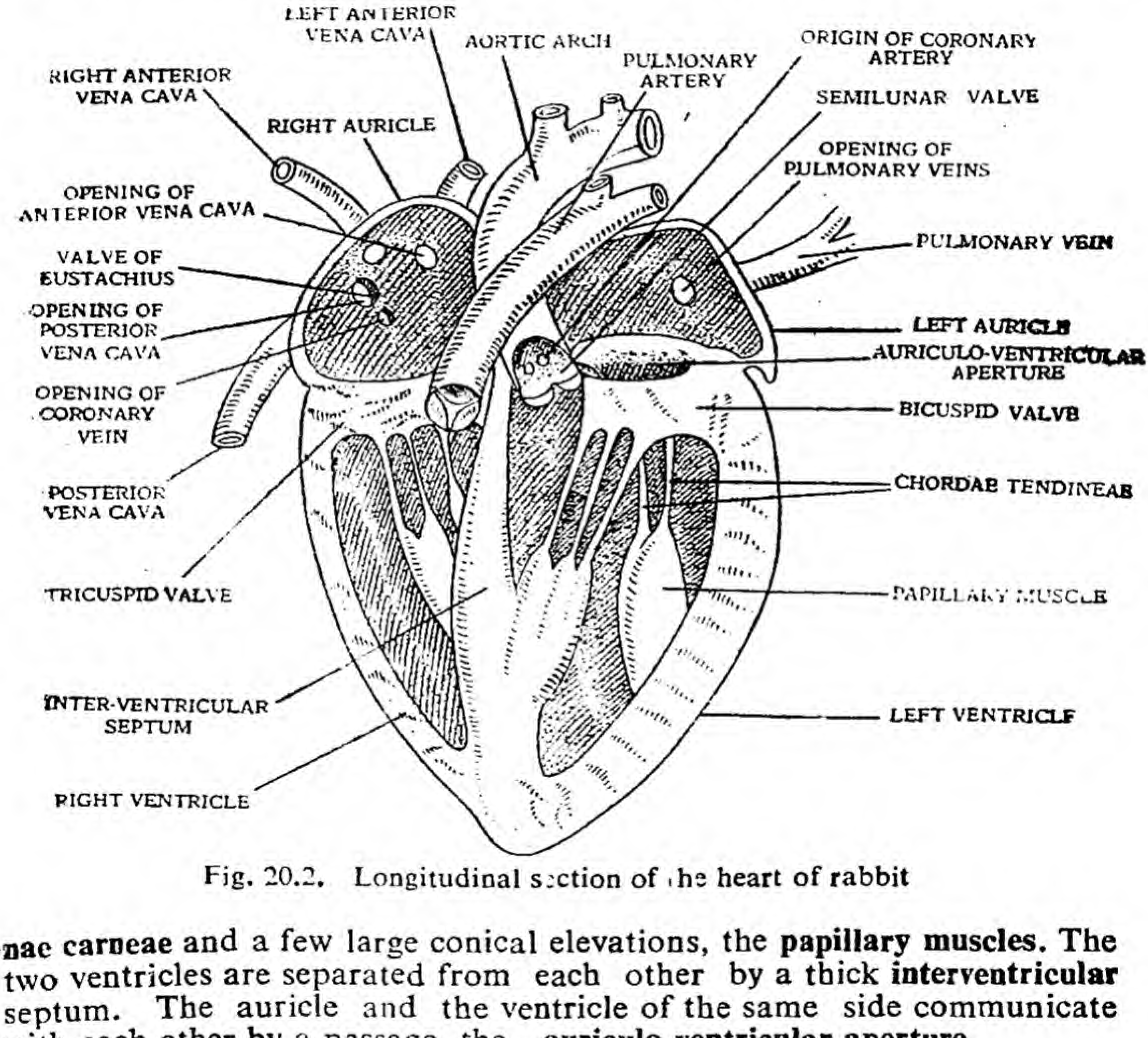


Fig. 20.2. Longitudinal section of the heart of rabbit

nae carneae and a few large conical elevations, the **papillary muscles.** The two ventricles are separated from each other by a thick **interventricular** septum. The auricle and the ventricle of the same side communicate with each other by a passage, the **auriculo-ventricular aperture.**

The right auricle receives three large vessels, the **right** and the **left precavals** or the **anterior venae cavae** and the **postcaval** or the **posterior vena cava.** The opening of the posterior vena cava into the right auricle is guarded by the **valve of Eustachius.** The right auricle also receives the **coronary sinus** whose opening is guarded by the **valve of**

Thebesius. The right auricle opens into the right ventricle through the **right auriculo-ventricular aperture** guarded by a one-way valve called the **tricuspid valve.** The valve consists of three membranous flaps which project into the ventricle. Their free edges are attached to the papillary muscles of the ventricle by a number of tough white cords, the **chordae tendineae.** The chordae tendineae serve to check the pushing of the flaps into the auricle during the contraction of the ventricle. From its left anterior angle, the right ventricle leads into a large blood-vessel, the **pulmonary artery,** which proceeds to the lungs. At the base of the pulmonary artery are found three pocket-shaped flaps, the **semilunar valves,** with their cavities directed away from the ventricle. They check the return of blood to the ventricle.

The left auricle receives two blood-vessels, the **right** and **left pulmonary veins.** It opens into the left ventricle by the **left auriculo-ventricular aperture** which is guarded by a one-way valve. This is known as the **bicuspid** or **mitral valve.** It consists of two flaps only. The free edges of these flaps are also attached by chordae tendineae to the papillary muscles of the ventricle. At its right anterior angle, the left ventricle leads into a large blood-vessel, the **aortic arch.** At the base of the aortic arch also are three pocket-shaped semilunar valves with their cavities facing away from the ventricle. These valves prevent the flow of the blood back into the ventricle.

(*e*) **Histological Structure.** The heart is in reality a highly modified blood-vessel. Like other vessels, its cavities are lined by an endothelium, here termed the **endocardium.** This is surrounded by a thick layer of cardiac muscle, the **myocardium.** The latter is invested by a thin delicate membrane, the **epicardium** or visceral pericardium. The cardiac muscle is composed of striated fibres which branch and anastomose freely and have thick dark cross bands, **intercalated discs,** giving the appearance of division into cells. (Fig. 5.8).

(*f*) **Working.** Working of the heart involves alternate contraction **(systole)** and relaxation **(diastole)** of its chambers. The contraction of a chamber reduces its volume and squeezes the blood out of it while the relaxation brings it back to the original size to receive more blood. The various chambers of the heart do not contract simultaneously but in a rhythmic fashion. A wave of contraction passes obliquely over the heart, beginning with the right auricle and followed in turn by the left auricle, right ventricle and left ventricle. This forces the blood from the auricles into the pulmonary and aortic arches via ventricles.

The right auricle receives the non-aerated blood from all over the body by the three venae cavae (Fig, 20.2) while the left auricle receives the aerated blood from the lungs by the pulmonary veins. When full, the auricles contract as mentioned above. This forces their blood into the corresponding ventricles behind through the auriculo-ventricular apertures whose valves open for this purpose. The blood does not return to the great veins (venae cavae and pulmonary veins) as the contraction of the auricles starts from the anterior end and proceeds

towards the ventricles pushing the blood in front of it. Moreover, the blood already present in the veins offers resistance to the blood returning into them from the auricles.

Now follows the contraction of the ventricles. This creates a considerable pressure on the blood contained in the ventricles. Due to this pressure, the flaps of the tricuspid and bicuspid valves are pushed forward and meet to close the auriculo-ventricular apertures. At the same time, semi-lunar valves are pressed and opened. With the result, the non-aerated blood from the right ventricle flows into the pulmonary artery and the aerated blood from the left ventricle enters the aortic arch. The flow of the blood from these blood-vessels back into the ventricles is prevented by the semi-lunar valves which get filled with blood and meet to close the apertures they guard. The pulmonary artery carries the non-aerated blood to the lungs for aeration. The aortic arch distributes the aerated blood to all the parts of the body where it again becomes non-aerated after supplying its oxygen to the tissues. The non-aerated blood from the body and the aerated blood from the lungs again come to the heart where the same sequence of events is repeated.

A noteworthy feature in the rabbit's heart is the fact that the aerated and non-aerated blood remain completely separate. With the result, all parts of the body (except the lungs) receive aerated blood. This makes the rabbit's heart superior to that of the frog which supplies mixed blood to the body. Further, in the rabbit, the blood, in order to circulate once round the body, has to pass twice through the heart, once through the right side and then the left. This type of circulation is called **double circulation.**

(*g*) **Efficiency**. The heart is able to carry on non-stop beating with the same efficiency throughout life and without getting fatigued because it rests for double the time it works. Contraction of the heart is followed immediately by relaxation but the latter is not followed at once by the next contraction. Before the next contraction occurs, there is a resting or recovery period in which no activity is shown. The recovery period actually amounts to more than twice the contracting time.

(*h*) **Control of Heart Beat.** A heart removed from the body continues to beat as long as supplied with the necessities of life. This shows that the rhythmic contractions (but not rate) of the heart are independent of the nervous and endocrine systems and have their mechanism in the heart itself. This mechanism comprises three masses of modified muscle-fibres, namely, **sinu-auricular node** situated in the wall of the right auricle close to the entry of the caval veins, **auriculo-ventricular node** lying in the inter-auricular septum and the **bundle of His** whose fibres extend from the auriculo-ventricular node to the wall of the ventricles (Fig. 20.3). The sinu-auricular node acts as a pacemaker. A wave of contraction originates from it and passes over both the auricles along the muscle fibres that fan out from the pacemaker. The auricular contraction cannot pass over the ventricles because the muscles of the

auricles and ventricles are not continuous, being separated by a ring of connective tissue. Stimulated by the auricular contraction, the auriculo-ventricular node sets up a fresh wave of contraction which spreads over both the ventricles along the bundle of His.

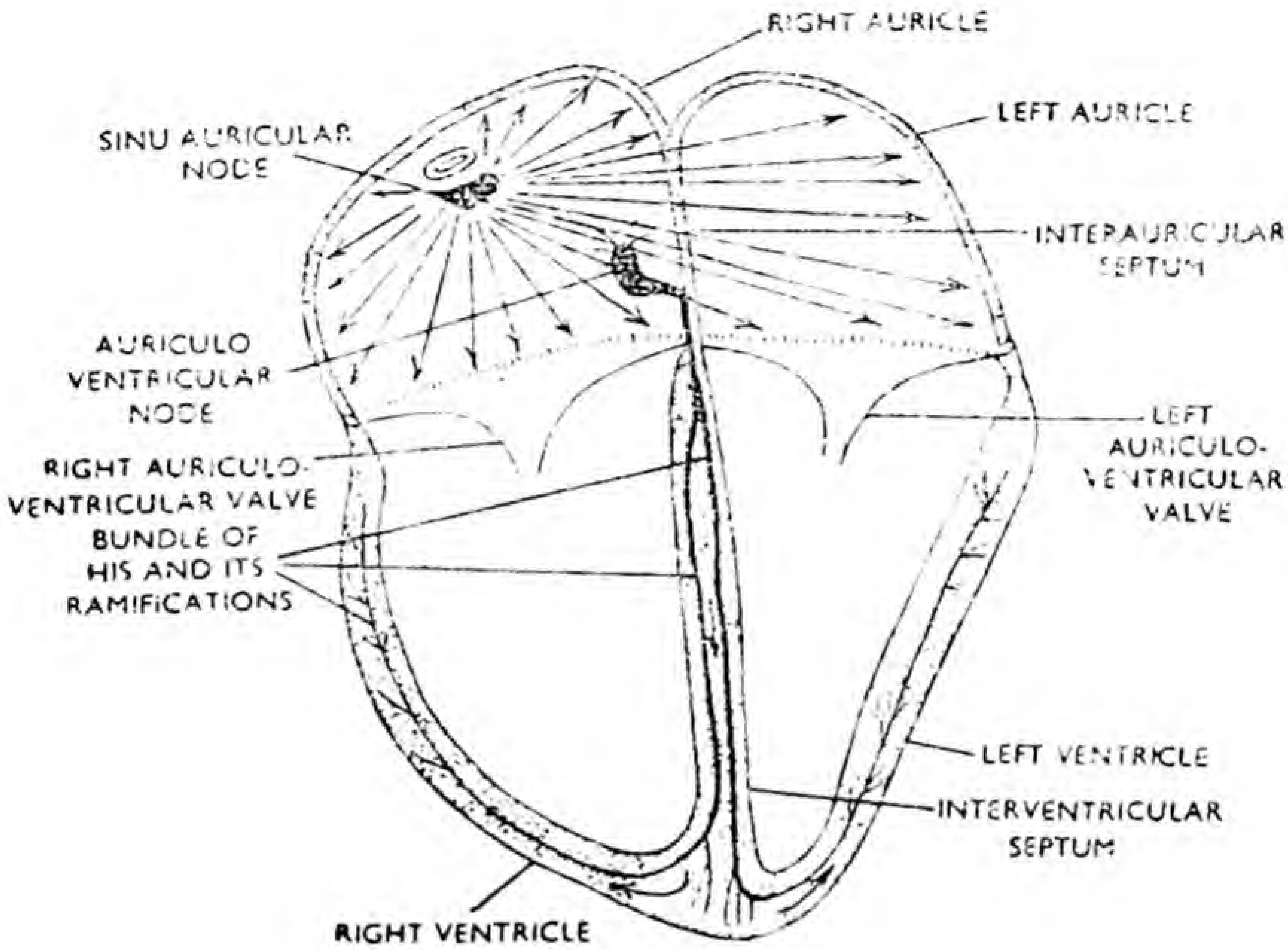


Fig. 20.3. Mechanism of heart beat.

The rate of the heart beat is, however, controlled by the nervous and endocrine systems. The nervous system affects through the **cardiac centre** in the medulla oblongata of the brain. This centre innervates the sinu-auricular node by two sets of fibres : **vagal** (parasympathetic) which retard the heart beat and **sympathetic** that accelerate the beat. Thus, the heart always works against a brake. The endocrine system affects the heart beat through two hormones, **epinephrin** and **norepinephrin**, secreted by the inner part or medulla of the adrenal glands. Both the hormones accelerate the heart beat, the latter under normal conditions and the former at the time of emergency.

Heart of Sheep

Heart of sheep or goat is dissected in the laboratory due to its large size. It only slightly differs from that of the **rabbit.** It has a lot of adipose tissue or fat filling the auriculo-ventricular and interventricular grooves. The coronary vessels supplying the heart muscle are quite prominent. The ductus arteriosus, a solid band joining the pulmonary arch with the aortic arch, is clear. The anterior venae cavae or precavals may unite and open into the right auricle by a common aperture. The right ventricle has a muscular band, the **moderator band** or **bundle of Leonardo,** connecting the anteriormost papillary muscle with the inter-

ventricular septum. For directions to dissect the heart, reference may be made to Zoology Practical Note Book for Pre-medical class by Deol and Dhami or Gupta and Verma.

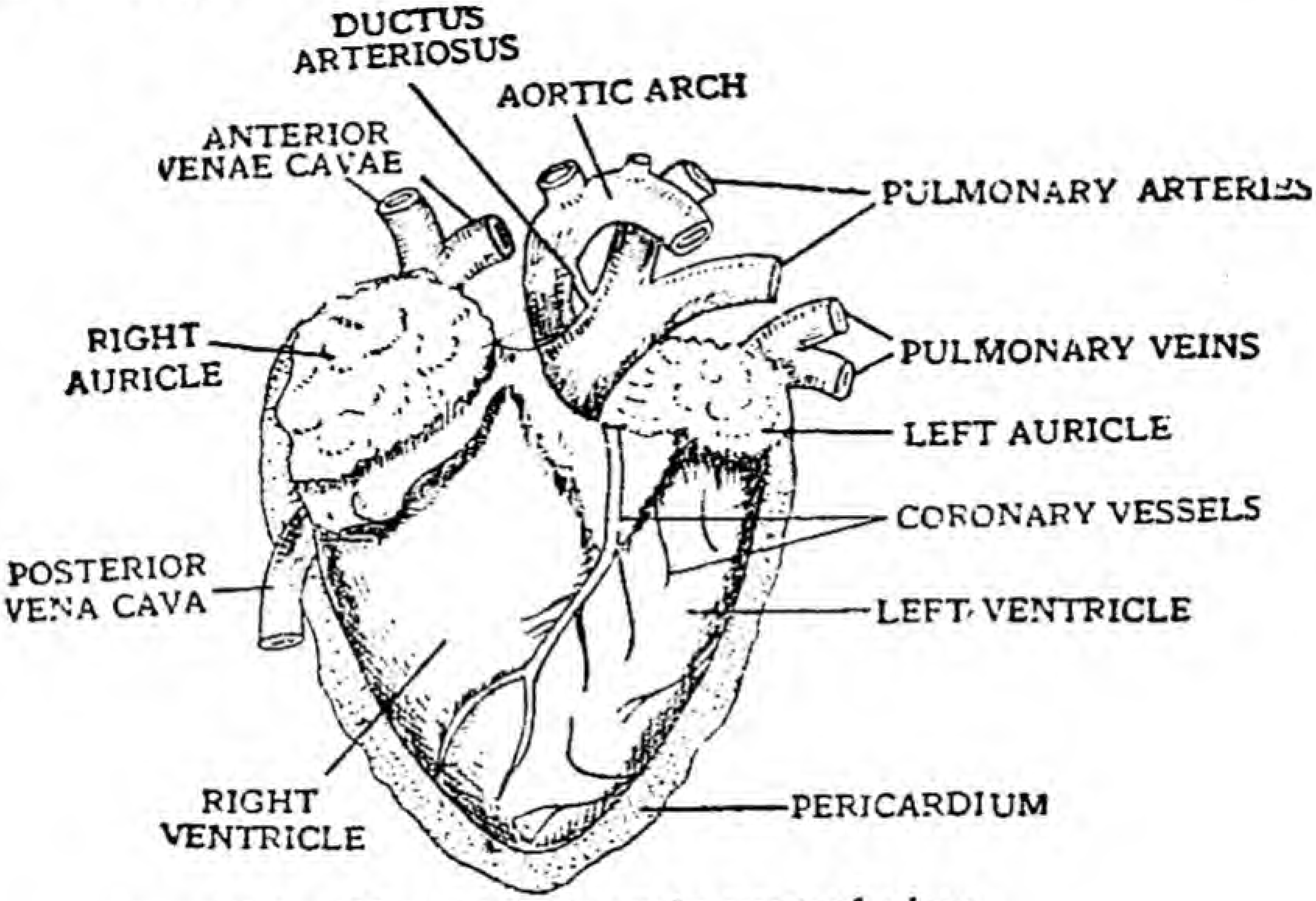


Fig. 20.4. Heart of sheep in ventral view

II. Blood-vessels

The blood-vessels are of two types : the **arteries** and the **veins.** They differ from each other in the following respects—

TABLE 10

Arteries	Veins
1. The arteries carry blood away from the heart for distribution to the body.	1. The veins bring blood from the body back to the heart.
2. They contain aerated blood except the pulmonary artery.	2. They contain non-aerated blood except the pulmonary veins.
3. The flow of the blood is fast and jerky. This is due to the heart beats.	3. The flow of the blood is slow and steady.
4. They have thick elastic walls and narrow lumen (Fig. 5.33).	4. They have thinner scarcely elastic walls and wide lumen (Fig. 5.33).
5. They are deep-seated.	5. They are superficial.
6. They have no valves in them.	6. They have valves to prevent back-flow of the blood and counteract gravity (Fig. 20.5).
7. They become empty after the death of the animal.	7. They contain blood even after the death of the animal.
8. When they are empty or cut across they retain their tubular form.	8. When these are empty or cut across, they collapse.

A large artery, the aortic arch, starts from the heart and gives off smaller arteries to the various organs of the body. An artery, on

entering its organ, divides into a number of smaller branches, the **arterioles**, which further divide repeatedly to form a network of very fine branches, the capillaries (Fig. 20.6). The walls of the capillaries are exceedingly thin, being only one-cell deep (Fig.5.34). The materials like food, gases and waste products, enter and leave the blood through the thin walls of the capillaries by diffusion. The capillaries, after the metabolic exchange, unite to form slightly larger vessels, the **venules,** which again unite to form a **vein.** The vein comes out of the organ ~~and joins~~ other veins. The veins from all over the body meet and ultimately form three large venae cavae which open into the heart. This is how blood circulates in the body distributing and collecting materials on the way.

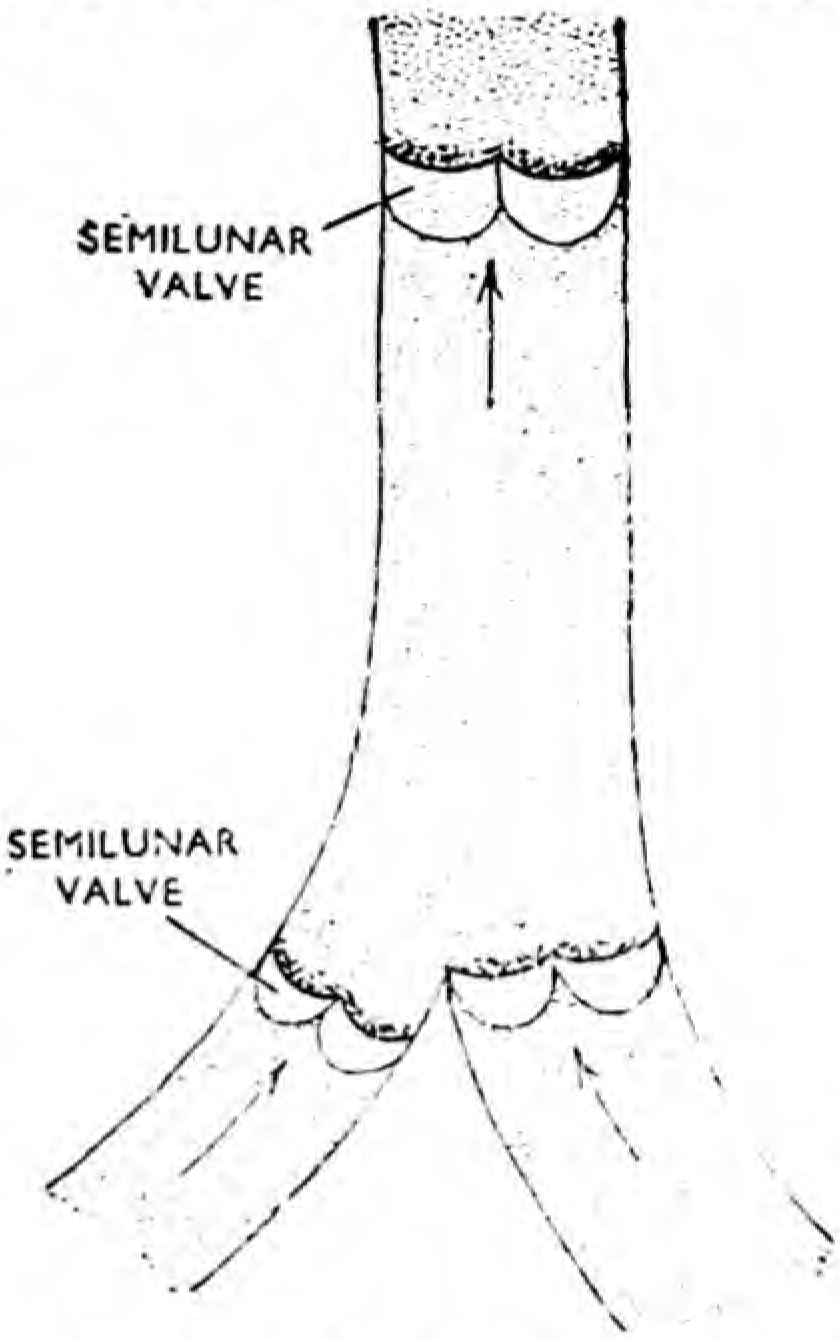


Fig. 20.5. Veins cut open to show the valves.

The distribution of the blood to the various parts of the body by the arteries is called the **arterial** system and the return of the blood from the different parts of the body to the heart through the veins is known as the **venous system.**

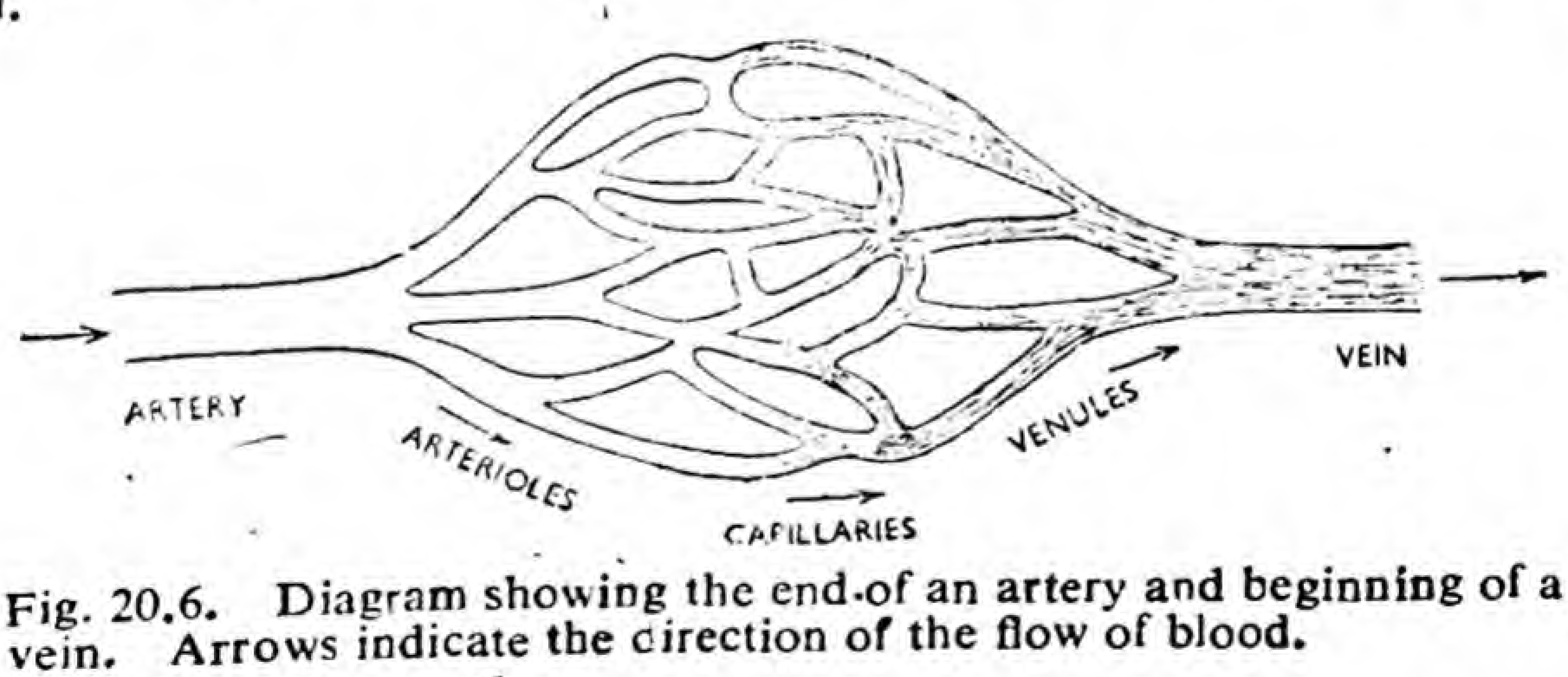


Fig. 20.6. Diagram showing the end of an artery and beginning of a vein. Arrows indicate the direction of the flow of blood.

1. Arterial System

The arterial system (Fig. 20.7) comprises two large blood-vessels arising directly from the heart and their branches to various organs. The large vessels are the **aortic arch** and the **pulmonary arch.**

(*i*) **Aortic Arch.** It arises from the left ventricle, curves round the left bronchus to the dorsal side of the heart and then runs backwards as the **dorsal aorta** through the thorax and abdomen along the mid-dorsal line just beneath the vertebral column. It gives off arteries all along its course to the organs near which it passes.

A pair of **coronary arteries** arise from the aortic arch just beyond its origin from the ventricle. They supply blood to the wall of the heart itself. The **innominate artery** leaves the aortic arch just in front of the

heart. It is very short and soon gives off a **left commom carotid artery** and then divides into two arteries, **right sub-clavian** and the **right common carotid.** The right sub-clavian gives rise to the **vertebral artery** which runs forwards through the vertebrarterial canal of the cervical vertebrae to supply the brain and the spinal cord, and the **internal mammary** or the **anterior epigastric artery** which proceeds backwards to supply the ventral wall of the thorax. The main trunk of the sub-clavian runs outwards as the **brachial artery** to the fore-limb. The two **common carotid arteries** are similar in their course and distribution. They run forwards through the neck just outside the trachea and each divides into two arteries near the larynx. These are the **internal carotid**

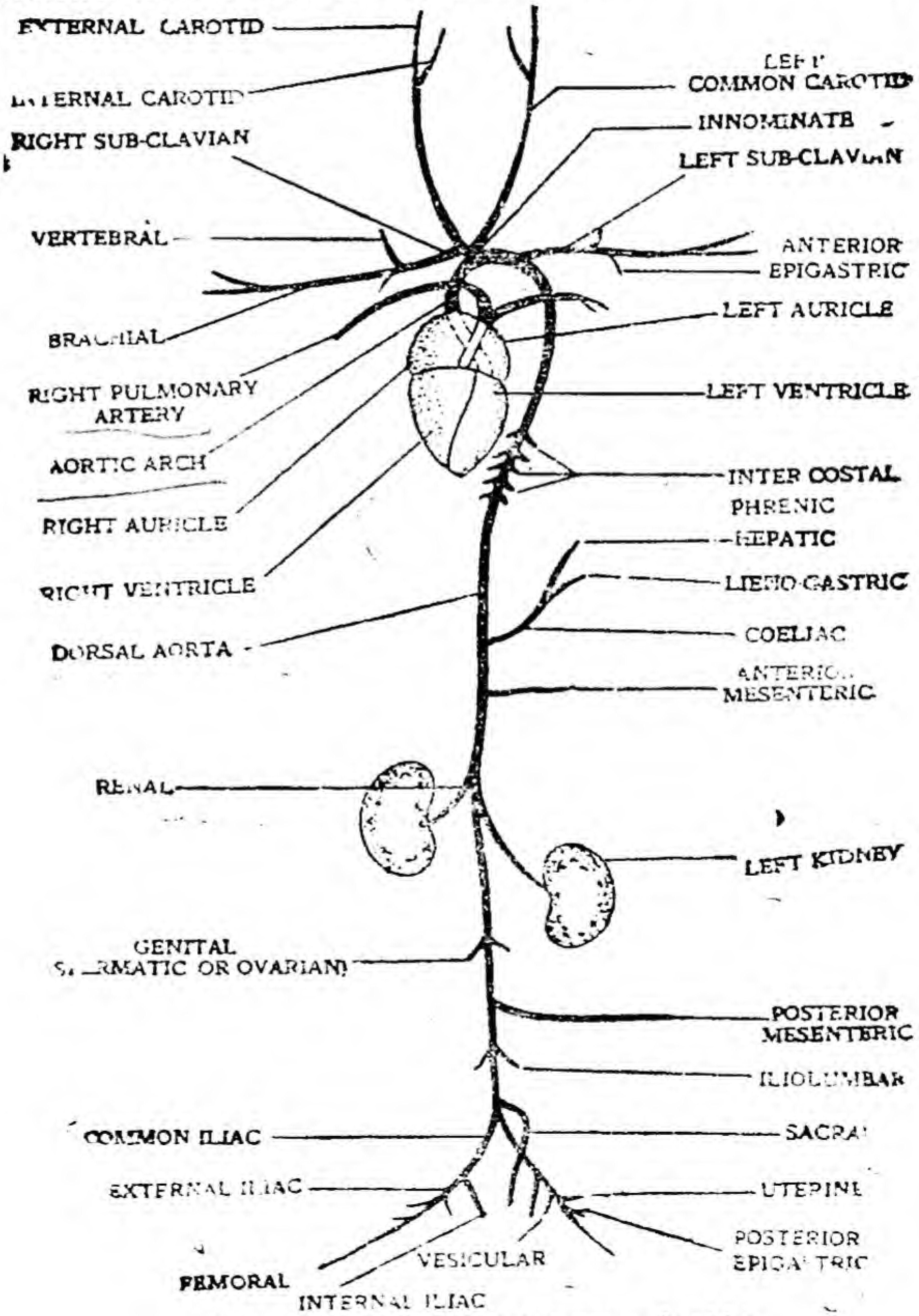


Fig. 20.7. The arterial system of rabbit

which sends blood to the brain and the **external carotid** which distributes the blood to the head and the face. The left common carotid artery may sometimes arise directly from the aortic arch. The left subclavian artery arises from the aortic arch on the left side and resembles its counterpart of the right side in its distribution.

A number of small paired arteries, the **intercostal arteries**, are given off by the dorsal aorta in the thorax. They supply blood to the thoracic wall. A pair of small **phrenic arteries** leave the aorta for the diaphragm behind the intercostal arteries. A large **coeliac artery** arises from the dorsal aorta behind the diaphragm, runs in the mesentery and divides into the **hepatic artery** to the liver and the **lieno-gastric** to the spleen and stomach. Another large artery, the **anterior mesenteric artery** leaves the aorta about twelve millimetres behind the coeliac artery. It also runs in the mesentery and sends branches to the pancreas, small intestine, caecum and the anterior part of the colon. The dorsal aorta then gives off a single pair of **renal arteries**, which carry blood to the kidneys. The two renal arteries spring from the aorta at different levels, the right being a little anterior. There is a pair of **genital arteries** in both rhe sexes. In the male, they are called **spermatic arteries** and supply blood to the epididymes, vasa deferentia and testes. In the female they are called the **ovarian arteries** and carry blood to the ovaries and uteri. A small **posterior mesenteric artery** arises behind the genital arteries. It runs in the mesentery and supplies blood to the hinder part of the colon and rectum. The dorsal aorta now gives off a pair of small **ilio-lumbar arteries** that carry blood to the body-wall. They may arise from the aorta directly or from the common iliac-arteries. In the pelvis the dorsal aorta divide into two large **common iliac arteries**. Each divides into **internal** and **external iliac arteries**. The internal iliacs supply the dorsal wall of the pelvic cavity. The external iliac gives off a **vesicular artery** to the urinary bladder, a **uterine artery** to the uterus in the female and the **posterior epigastric artery** to the ventral abdominal wall. It then continues as the **femoral artery** to the hind limb. The **sacral artery** arises from the dorsal side of the aorta close to the point of its bifurcation and proceeds backwards to the tail. A series of small median arteries arise from the dorsal side of the aorta and supply the dorsal abdominal wall.

(*ii*) **Pulmonary Arch.** It arises from the right ventricle and curves to the dorsal side of the heart where it divides into two, the right and left pulmonary arteries, each going to its corresponding lung. This artery takes the non-aerated blood to the lungs for aeration.

2. Venous System.

The venous system (Fig. 20.8) consists of four types of veins : the **venae cavae** with their tributaries, the **pulmonary veins**, the **portal vein** and the **coronary sinus**.

(*i*) **Venae Cavae.** There are three venae cavae as already mentioned. They open into the right auricle by separate apertures. Two of them, the **anterior venae cavae** or the **precavals**, bring blood from the anterior part of the body while the third, the **posterior vena cava** or the **post-caval**, comes from the hinder region of the body.

The **right anterior vena cava** is formed by the union of five veins, namely, the **internal jugular** from the brain ; the **external jugular** from the head and neck ; the **sub-clavian** from the fore-limb ; the **intercostal** from the muscles of the anterior ribs ; and the **azygos** from the muscles of the posterior ribs of both the sides.

The **left anterior vena cava** is formed by the same branches as the right except that there is no azygos vein on this side.

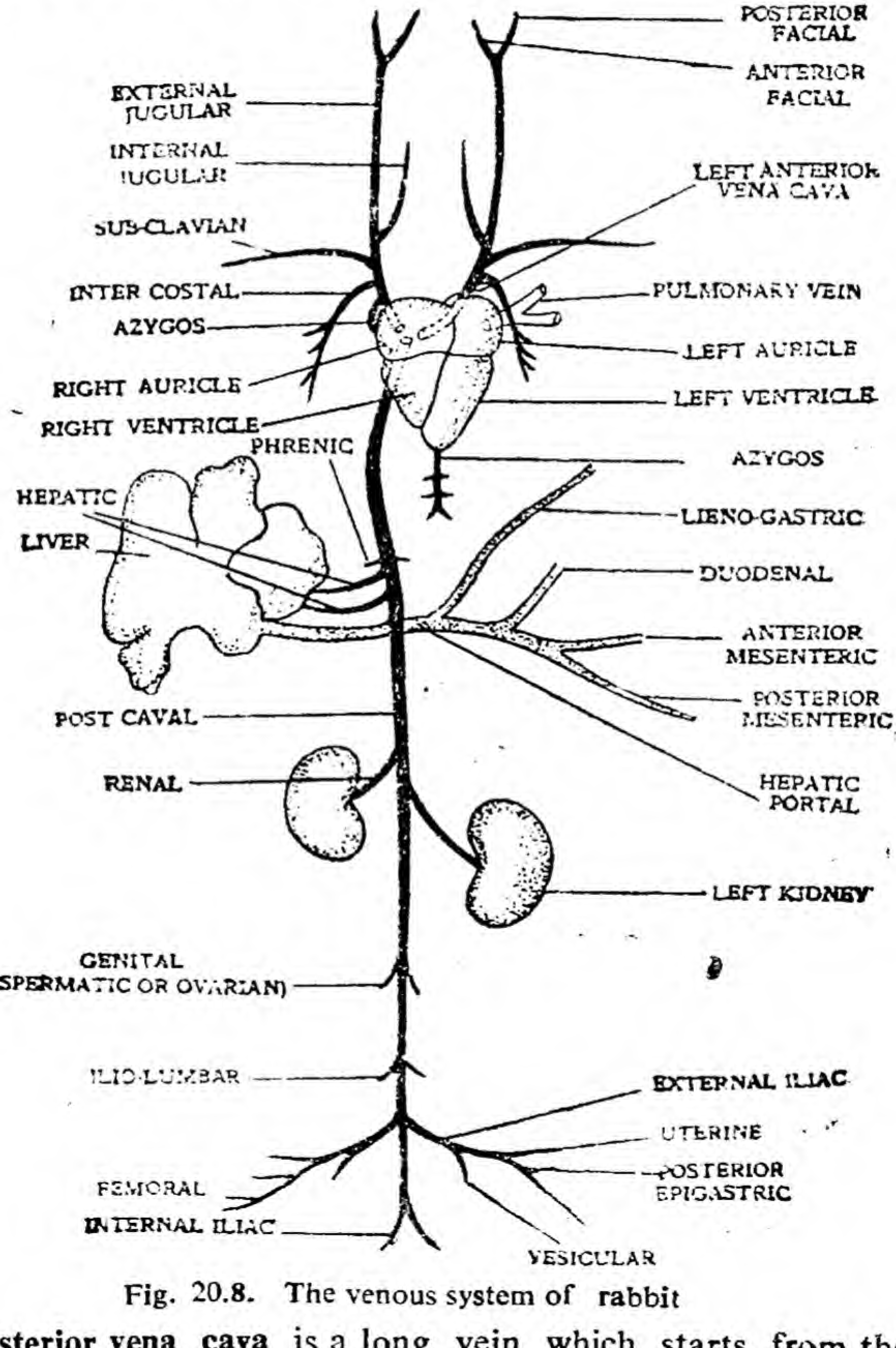


Fig. 20.8. The venous system of rabbit

The **posterior vena cava** is a long vein which starts from the base of the tail, runs forwards along the middle line through the abdomen and thorax and finally opens into the right auricle. On the way, it

receives a number of veins. It is formed posteriorly by the union of a pair of **internal iliac veins** that bring blood from the back of the thighs. It is soon joined by a pair of large **external iliac veins**. Each external iliac vein is formed by the union of the **femoral vein** from the hind limb, the **posterior epigastric vein** from the ventral abdominal wall, the **uterine vein** from the uterus in the female, and the **vesicular vein** from the urinary bladder. A pair of **ilio-lumbar veins** collect blood from the dorsal body-wall and open into the posterior vena cava in front of the external iliacs. The left ilio-lumbar vein sometimes runs forwards parallel to the posterior vena cava and joins the renal vein of its side. A pair of **genital veins** now join the posterior vena cava. In the male they collect blood from the testes and are called the **spermatic veins** In the female they bring blood from the ovaries and are known as the **ovarian veins**. The two **renal veins** of the two sides open into the posterior vena cava at different points, the right being a little anterior. They return blood from the kidneys. After receiving the renal veins, the posterior vena cava passes through the liver from which it collects blood by a few **hepatic veins**. Lastly, a pair of small **phrenic veins**, which bring blood from the diaphragm, join the posterior vena cava.

(*ii*) **Pulmonary Veins**. There is a pair of pulmonary veins which collect blood from the lungs. They unite to open by a common aperture into the dorsal wall of the left auricle. They differ from the above mentioned veins in having the aerated blood in them.

(*iii*) **Portal Vein**. A portal vein may be defined as a vein which collects blood from certain organs and distributes it to some other organ instead of carrying it to the heart. There is only one portal vein in rabbit. It is called the **hepatic portal vein**. It is a large vessel running in the mesentery and formed by the union of four important veins, namely, the **lieno-gastric** from the stomach and spleen, the **duodenal** from the duodenum and pancreas, the **anterior mesenteric** from the ileum, caecum, colon and anterior part of the rectum, and the **posterior mesenteric** from the hinder part of the rectum. After collecting blood from the alimentary canal, spleen and pancreas by the above branches, the hepatic portal vein enters the liver and distributes its blood to it by a network of capillaries.

The hepatic portal vein along with its tributaries forms the **hepatic portal system**. This system is of great significance to the animal. By this system, the blood, with the various products of digestion comes from the alimentary canal to the liver. The liver cells separate from this blood the excess of sugar and store it as glycogen. The liver cells also convert the harmful ammonium salts into harmless urea to be ultimately eliminated by the kidneys. The portal system, thus, acts as a short circuit carrying the various materials to the desired organ directly without being first carried round the heart and lungs.

The rabbit lacks the renal portal system. This is due to an evolutionary change. The renal portal system is well developed in fishes and amphibians, gets reduced in reptiles and finally disappears in the mammals. This change is correlated to the change from the aquatic to the

terrestrial mode of life. In aquatic animals (fishes and amphibians) blood from the posterior half of the body passes through the kidneys so that the latter may bring its osmotic pressure to a level that does not permit the diffusion of outside water into the blood. The surrounding water can diffuse into the blood through the mucous membrane of the buccal and pharyngeal cavities and gills in the fishes and through the naked skin in the amphibians. Mammals, being terrestrial, have no such problem and hence have dispensed with the renal portal system.

(*iv*) **Coronary Sinus.** The non-aerated blood from the wall of the heart is returned by a number of veins, most of which converge to form the **coronary sinus**. The coronary sinus opens into the right auricle through an aperture guarded by the **valve of Thebesius**. Some veins from the heart do not join the coronary sinus and open independently into the right auricle. These veins are known as the **venae cordis minimae** and their openings into the right auricle as the **foramina of Thebesius.**

III. Blood

(*a*) **Structure.** The blood is a fluid tissue constantly circulating in the body. It is opaque, somewhat sticky, slightly heavier than water bulk for bulk. It has a saltish taste and a faint alkaline reaction. It is bright red when aerated and purple when non-aerated. It consists of a liquid medium, the **plasma,** containing three types of cells or corpuscles : the **red corpuscles** or **erythrocytes**, the **white corpuscles** or **leucocytes** and the **platelets** or **thrombocytes** (Fig. 20.9). None of them divides or multiplies in the blood.

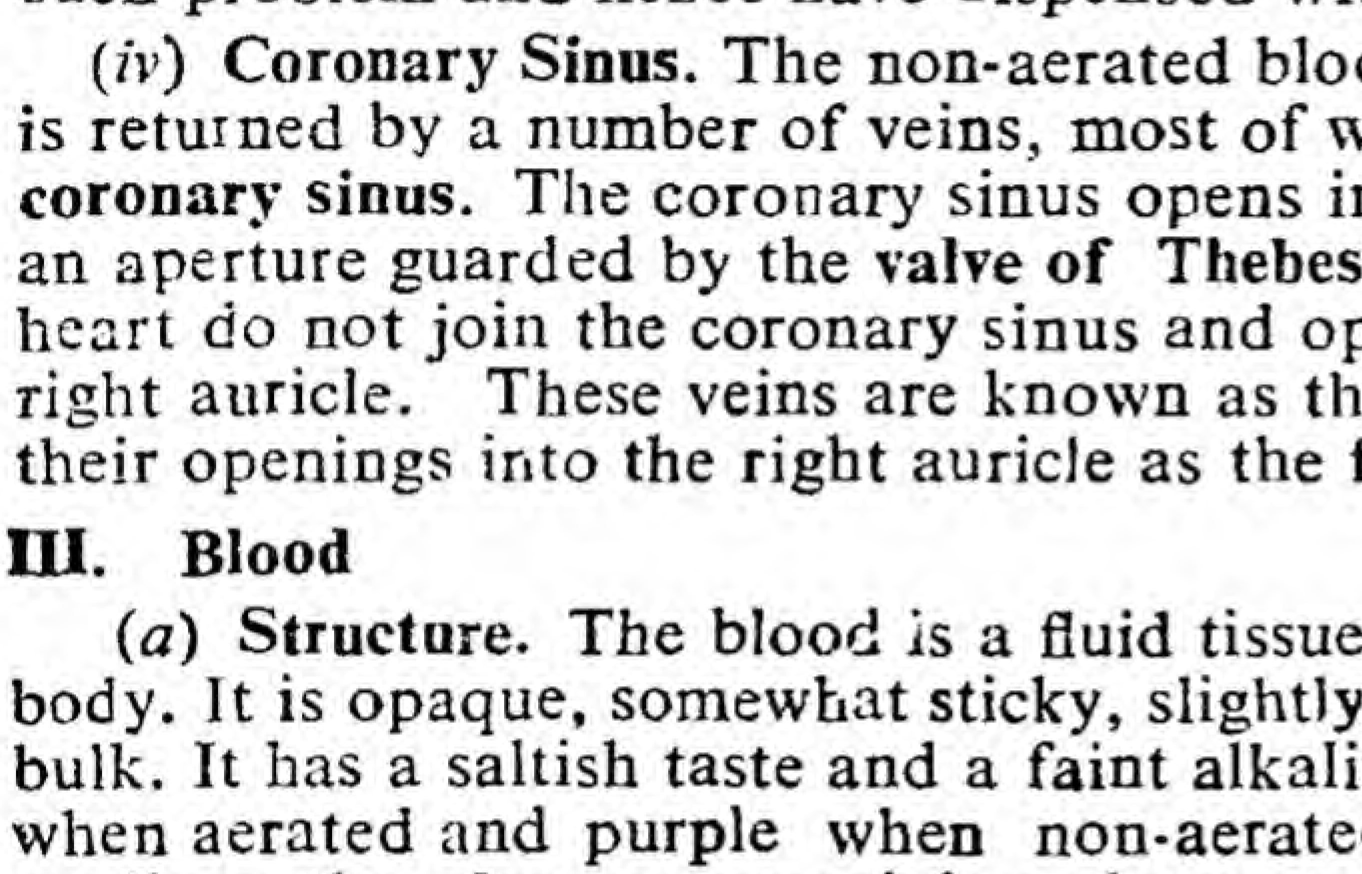


Fig. 20.9. The blood of rabbit

(*i*) **Plasma** (Liquor Sanguinis). It is a pale-yellow liquid having a number of inorganic salts in solution and a few blood proteins in colloidal state. Chloride and bicarbonate of sodium among the organic salts and fibrinogen from the proteins deserve special mention. Many other substances like food materials, waste materials, gases and hormones are also invariably found in the plasma but they do not form its integral part. They enter or leave the plasma at intervals. They are, in fact, on the way to their destination in the body.

(*ii*) **Red Corpuscles** (Erythrocytes). These are denucleated, biconcave, circular discs. They are far more numerous than the white corpuscles. They are bounded by a highly elastic membrane which enables them to pass through fine capillaries having diameter less than that of their own. Individual red corpuscles are pale-yellow in colour but they appear red in a mass. They impart red colour to the blood. The colour is due to the presence of a respiratory pigment, the **haemoglobin,** in them. The red

corpuscles are produced in the red bone marrow and the worn-out ones are destroyed by phagocytes present in the blood itself and in the spleen and liver in particular. Their short life is probably due to the absence of nuclei.

(iii) **White Corpuscles** (Leucocytes). These are nucleated, colourless and irregular bodies larger than the red corpuscles. They can change their shape and are capable of performing slow amoeboid movements. They are of two main types : the non-granular leucocytes and the granular leucocytes. The former are produced in the lymph nodes and the latter are formed in the red bone marrow. Both types are divisible into subtypes. The non-granular leucocytes are of two types : **monocytes** and **lymphocytes**. The monocytes are as large as the red corpuscles and have a rounded nucleus almost filling the corpuscle. The lymphocytes are much larger and have irregular nucleus. The granular leucocytes are of three types : **basophils** with one- to three-lobed (usually bilobed) nucleus and coarse granules, **eosinophils** also with one- to three-lobed nucleus and coarse granules and **neutrophils** with many-lobed nucleus and fine granules.

(iv) **Blood Platelets.** These are rounded or oval, non-nucleated, granular discs smaller in size than the red and white corpuscles. They readily disintegrate on exposure to air and thereby aid in blood clotting.

(b) **Blood Clotting**. In the injured parts the blood-platelets disintegrate and release a chemical substance which precipitates fibrinogen of the plasma into **fibrin** threads. These threads entangle the corpuscles and form a clot. The latter plugs the injured part and stops bleeding. In the closed vessels the blood has a substance called **heparin** to prevent its clotting.

(c) **Functions of the Blood**. The blood plays a vital role in the animal body and is often described as the "river of life". Each one of its constituents is important.

(i) **Plasma**. It carries the digested food from the intestine (and liver) to the rest of the body for nourishment. It collects carbon dioxide from all the tissues and brings it to the lungs for expiration. It transports urea from the liver to the kidneys for removal as urine. It distributes hormones from the endocrine glands to the parts where needed. It supplies materials to the glands for the preparation of their secretions. It equalises the body temperature by carrying heat from the heat-producing tissues, like the muscles and glands, to others where no or little heat is produced. It keeps all the tissues moist.

(ii) **Red Corpuscles**. These carry oxygen from the lungs to other organs for oxidation of food to release energy for life activities. Oxygen travels in the blood as an unstable compound, oxyhaemoglobin, which is formed in the lungs by the chemical union of oxygen and haemoglobin and which breaks up in the tissues into oxygen and haemoglobin.

(iii) **White Corpuscles**. These act as the soldiers, scavengers and builders of the body. The neutrophils eat up the foreign germs that may happen to enter the body. The lymphocytes produce antitoxins to neutralize the

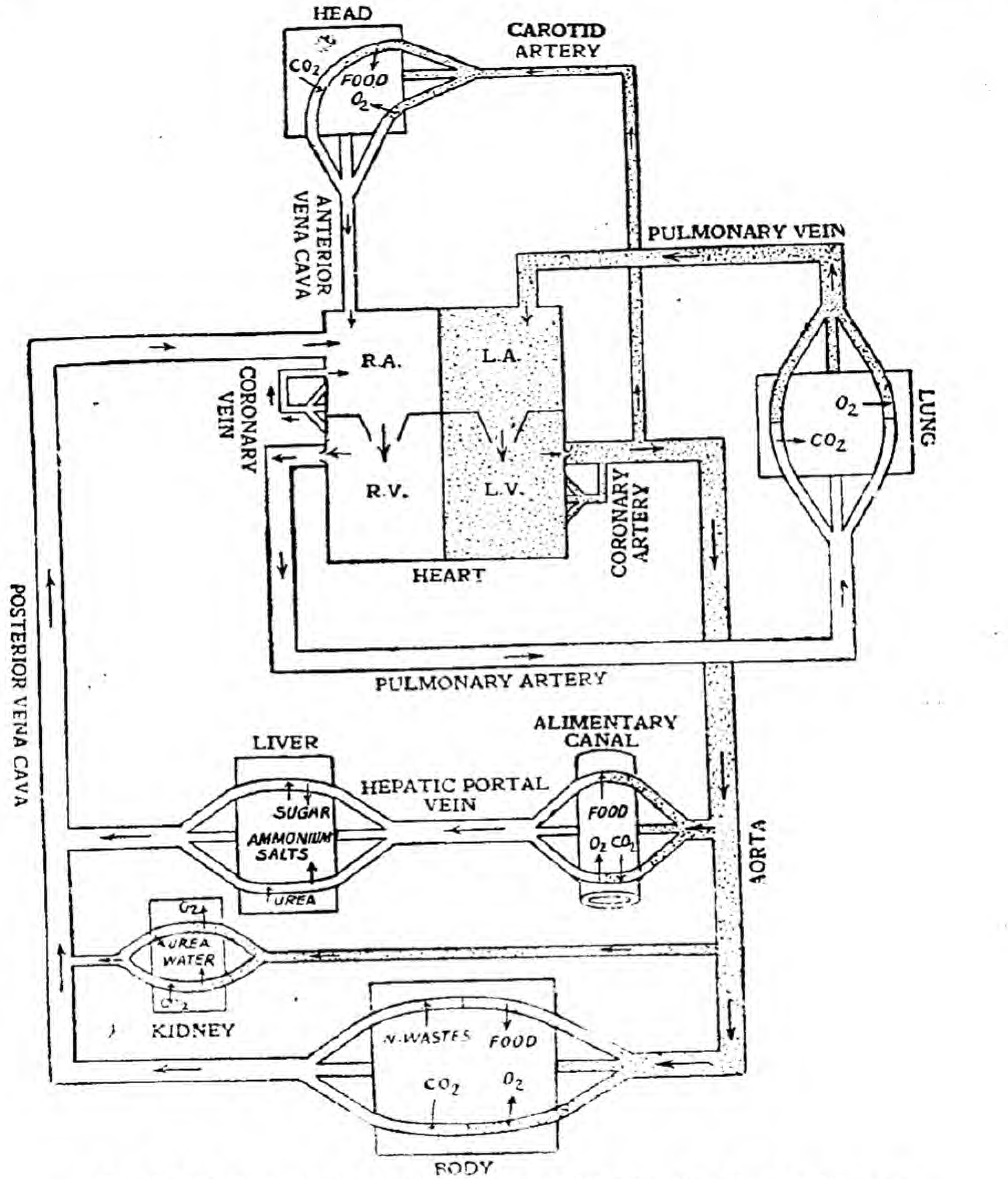


Fig 20.10. Scheme of circulation in rabbit showing the exchange of materials in the important organs (N=Nitrogenous)

toxic effect of the foreign germs. The monocytes devour the injured and dead cells to clean the body. Eosinophils and basophils help in the healing of wounds.

(*iv*) **Blood-platelets.** These aid in blood-clotting.

LYMPHATIC SYSTEM

The lymphatic system helps in the exchange of materials between the blood and the tissue cells. It also maintains the volume of blood in the blood-vessels by restoring to them the blood that oozes out through the thin capillary walls.

This system consists of a colourless fluid, the **lymph** ; a network of fine channels, the **lymphatic capillaries** ; tubes of varied size, the **lymphatic vessels** ; and the **lymph nodes** (Fig. 20.11).

(*a*) **Lymph.** The lymph consists of two parts : a fluid matrix or **plasma** and amoeboid cells or **white corpuscles**. Both these components escape from the blood through thin walls of the blood-capillaries, the plasma by ultrafiltration, *i.e.* diffusion under pressure, and the white corpuscles by amoeboid locomotion. The lymph is, thus, the blood without red corpuscles. The lymph surrounds the tissue cells filling up the intercellular spaces (Fig. 20.12). The lymph acts as a "middle man". It hand over the food, oxygen and hormones from the blood to the tissue cells and the waste materials from the latter to the blood.

(*b*) **Lymphatic Capillaries.** From the intercellular spaces the lymph passes into the lymphatic capillaries which are interwoven but not connected with the blood-capillaries. They are quite difficult to observe They are wider than the blood-capillaries and their diameter is not uniform. They have extremely thin wall which consists of a single layer of flat endothelial cells.

(*c*) **Lymphatic Vessels.** From the lymphatic capillaries, the lymph flows into the lymphatic vessels which are formed by the confluence of the lymphatic capillaries. The lymphatic vessels resemble the veins in structue except that they have thinner walls and more numerous valves. The smaller lymphatic vessels unite to form larger vessels which in turn converge to form two main lymphatic vessels or trunks called the **thoracic duct** and the **right lymphatic duct**. The thoracic duct collects lymph from the entire body except the right side of the head, neck and thorax and right fore-limb. It starts in the abdomen from a **receptaculum chyli** into which empty the **lacteals** or lymphatic vessels of the intestine. It runs forwards beneath the vertebral column and opens into the left external jugular vein close to the latters junction with the subclavian vein. The right lymphatic duct drains the lymph from the right side of the head, neck and thorax and the right fore-

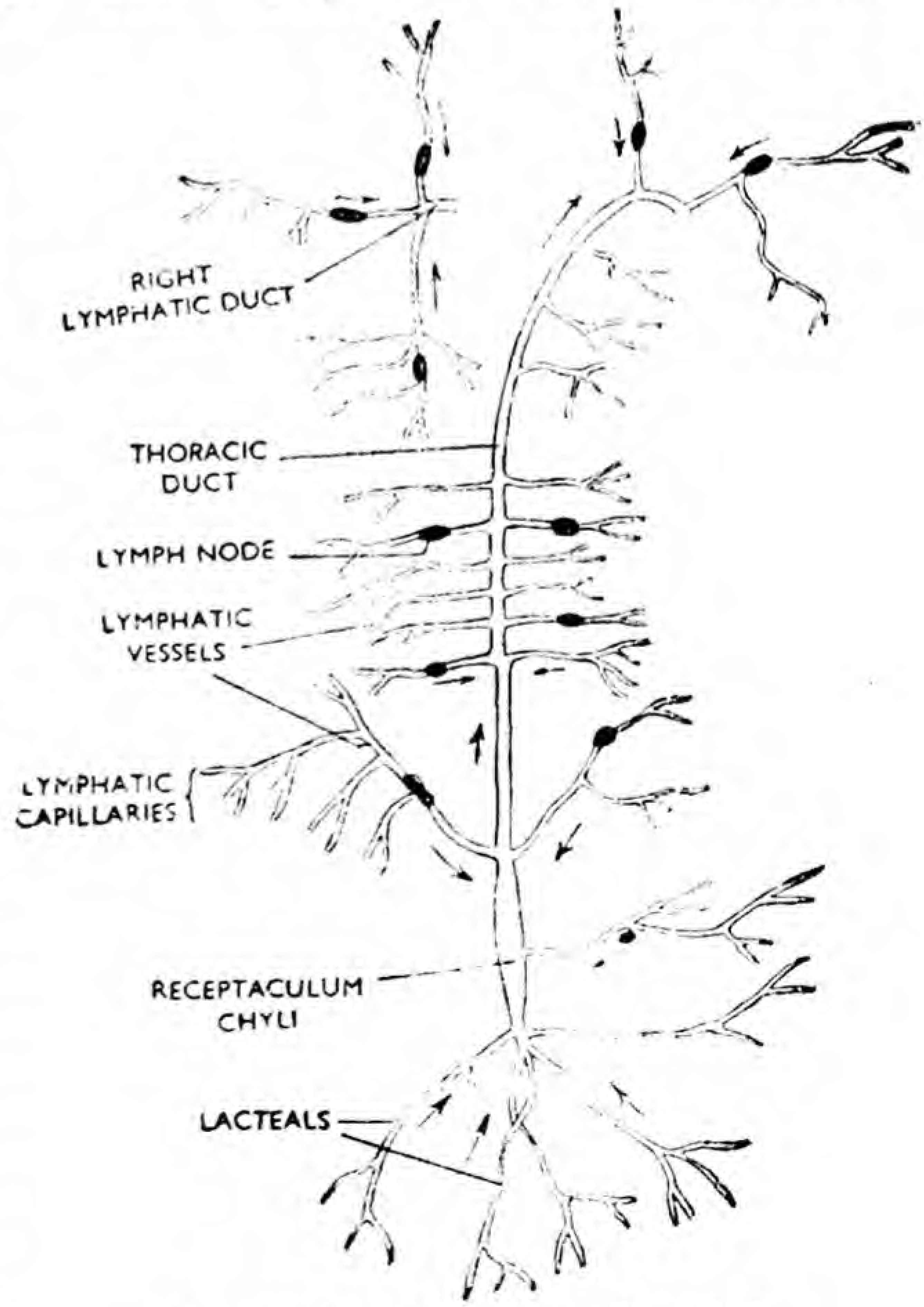


Fig. 2011. The lymphatic system

limb. It opens into the right external jugular vein just near its union with the right subclavian vein.

(*d*) **Lymph Nodes.** The lymph nodes lie at intervals in the course of the lymphatic vessels. They are masses of connective tissue with abundant white corpuscles. The lymph passes through them. They add white corpuscles to the lymph if it runs short of them and also rid it of bacteria.

The lymph moves through the lymphatic vessels and lymph nodes largely by muscular contractions of various parts of the body, tending to squeeze the fluid along.

Spleen

It is difficult to classify the spleen in any system. From its functions, it can be said to form a part of the circulatory system.

Structure. The spleen is an elongated, curved, dark-red, organ held in the mesentery close to the posterior border of the stomach. It has a muscular wall surrounding a pulpy substance that contains arterial capillaries, venous sinuses and lymphoid tissue.

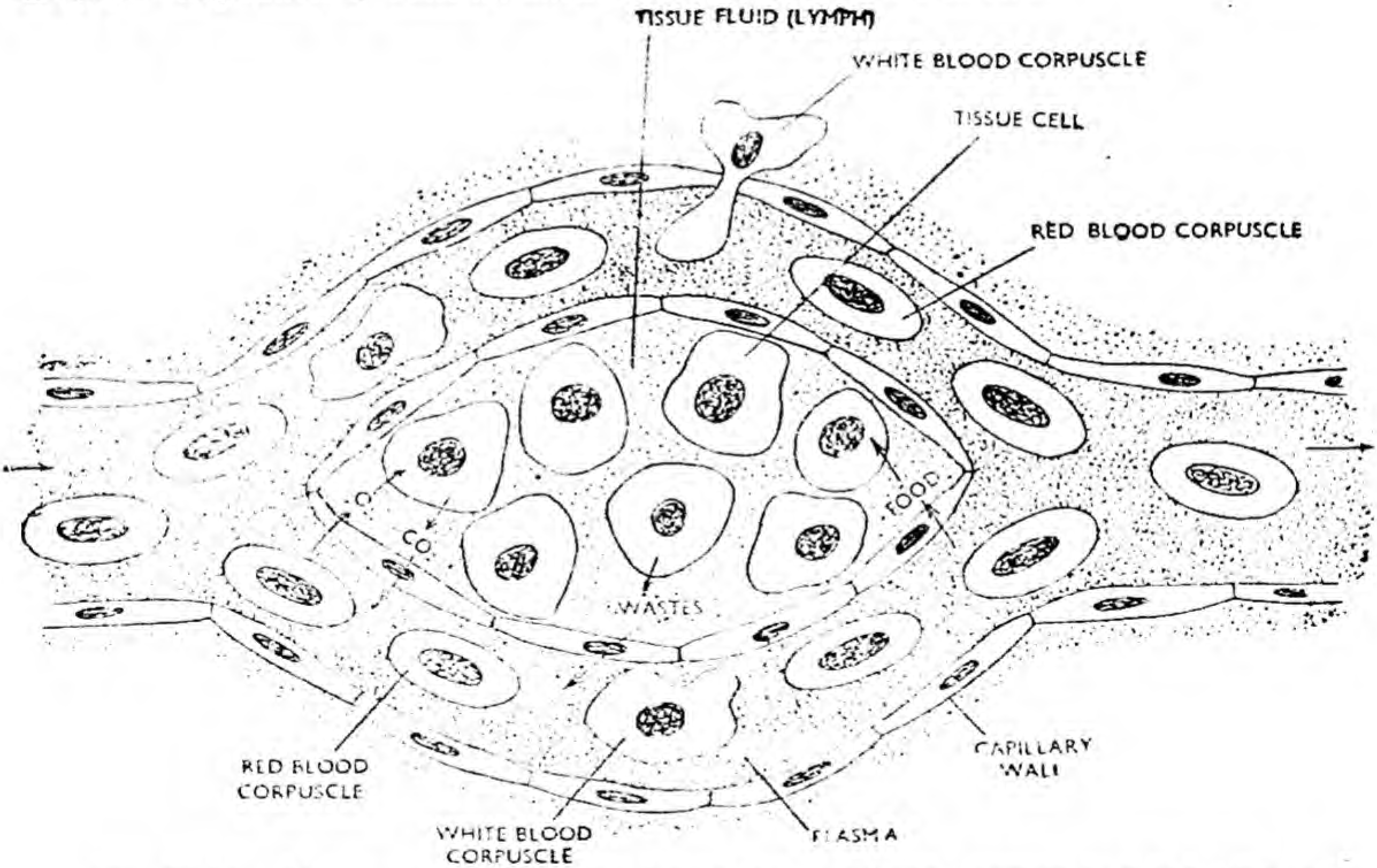


Fig. 20.12. Diagram showing how tissue fluid or lymph serves as a medium of exchange of materials between the blood and body cells. One white corpuscle is escaping through the wall of a capillary.

Functions. The spleen performs a few very important functions. Some of the cells of the spleen are called **macrophages.** These cells destroy the old worn out red corpuscles. When the animal is at rest and needs less oxygen due to slow metabolism, some red corpuscles are stored in the spleen. But during active life, when the animal requires

more oxygen, the stored corpuscles are released into the blood stream. Under certain conditions, the spleen produces new red and white corpuscles. The foreign germs are also destroyed in the spleen.

TEST QUESTIONS

1. What role does the circulatory system play in the animal body ? Name the two types of blood-vessels and bring out the differences between them.

2. Give a full account of the structure and working of the heart of rabbit.

3. Describe the structure and functions of the mammalian blood.

4. How does a portal vein differ from other veins ? Name and describe the portal system found in rabbit. What is the importance of portal system.

5. Name and describe the blood-vessels connected with the liver of rabbit.

6. How would you account for the following ?

(*a*) Auricles have thinner walls than the ventricles ?

(*b*) The venous blood is purplish red.

(*c*) Blood does not coagulate in the blood-vessels but readily clots outside them.

(*d*) Blood moves with jerks in the arteries.

(*e*) Heart has striped muscles unlike other viscera.

7. Give a brief note on the lymphatic system.

8. Give an account of the arterial or venous system of rabbit.

CHAPTER 21

Oryctolagus cuniculus

(The Rabbit)

NERVOUS SYSTEM

The nervous system controls the working of all parts of the body. It receives impulses from the sense organs, co-ordinates them and relays impulses to the effector organs like muscles and glands. It preserves the impressions of previous impulses to guide the animal in future. These impressions are described as the experiences.

Parts of the Nervous System. The entire nervous system is structurally continuous and functionally integrated. However, for convenience in description, it is divided into three main parts—the **central nervous system**, the **peripheral nervous system**, and the **autonomic nervous system.**

I. CENTRAL NERVOUS SYSTEM

The central nervous system is situated along the **mid-dorsal line of** the body. It consists of two structures : **brain and spinal cord.**

1. Brain (Figs. 21.2 to 21.5)

Morphology. The brain forms the anterior part of the central nervous system and lies in the cranial cavity of the skull. It is soft, whitish structure, somewhat flattened and about twice as long as broad. It develops from the anterior enlargenment of the neural tube of the embryo (Fig. 21.1A). This enlargement first gets transformed, by differential growth, into three swellings, the **primary cerebral vesicles** (Fig. 21.1B). These are individually called the **fore-brain, mid-brain** and **hind-brain.** The primary cerebral vesicles then give rise to the various parts of the brain by changes involving bulging, thickening and folding in them.

(*a*) **Fore-brain.** Paired outgrowths from the anterior end of the fore-brain give rise to **cerebral hemispheres.** Anteroventral parts of the cerebral hemispheres become modified into **olfactory lobes.** The rest of the fore-brain forms **diencephalon**. The embryonic fore-brain, thus, gives rise to three parts of the adult brain.

(*i*) **Olfactory Lobes.** The olfactory lobes form the anteriormost part of the brain. They are club-shaped bodies, each differentiated into two egions : the **olfactory bulb** projecting in front of the cerebral hemisphere and the **olfactory tract** concealed beneath the cerebral

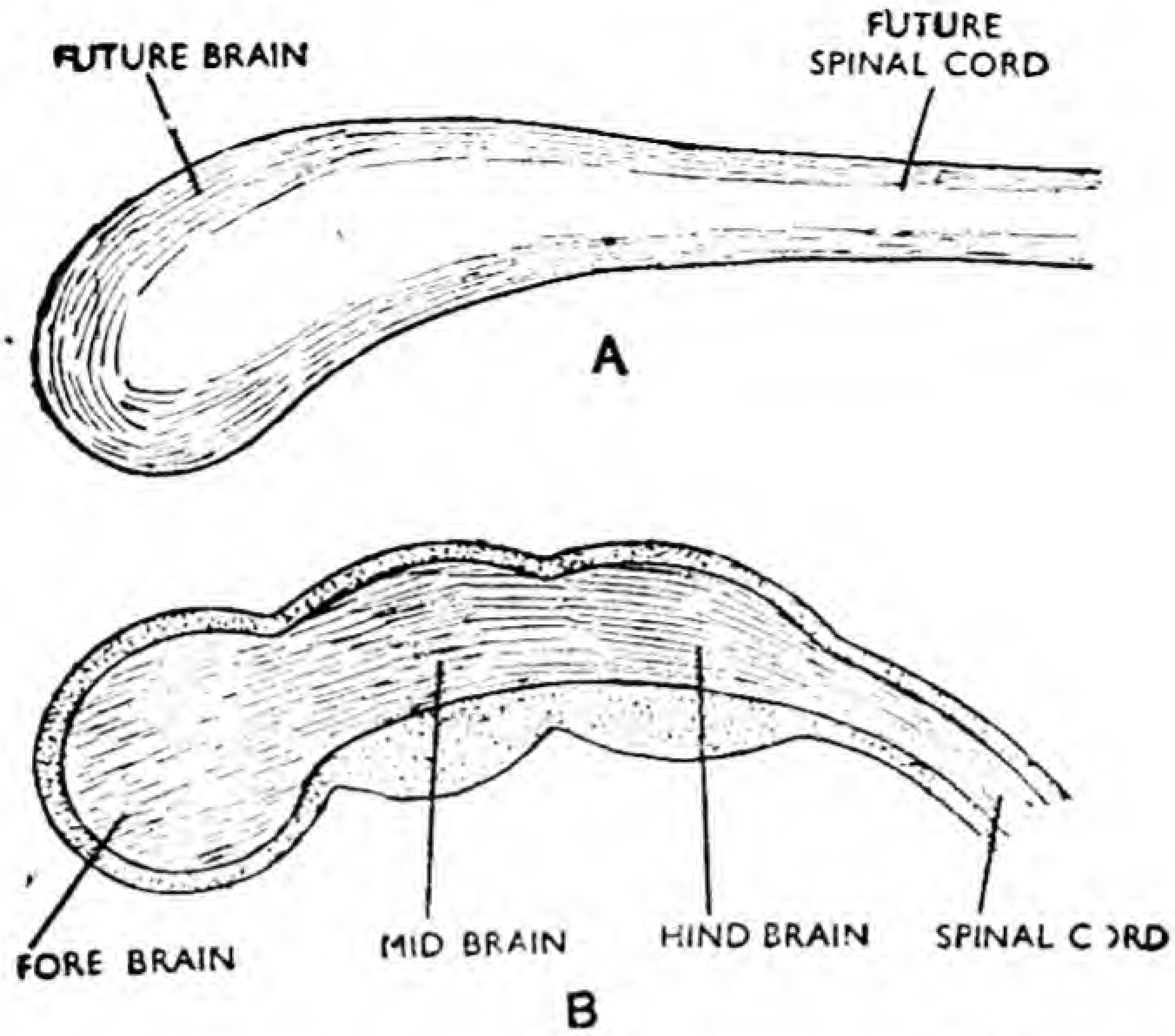


Fig. 21.1. A—Neural tube B—Primary cerebral vesicles

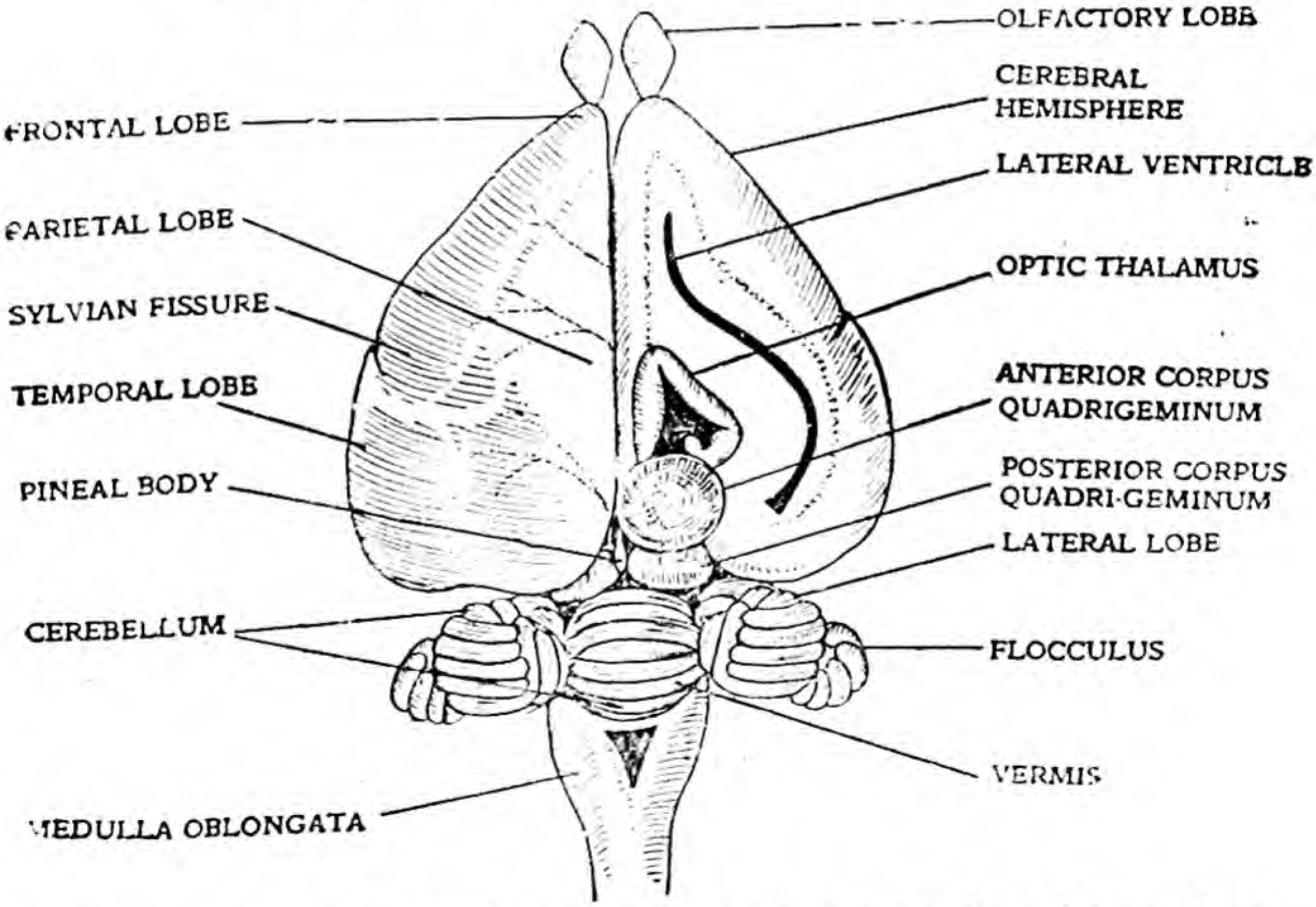


Fig. 21.2. The brain of rabbit—dorsal view (a part of the right cerebral hemisphere has been removed to show diencephalon and optic lobes)

hemisphere. The olfactory lobes are relatively small, indicating less reliance of the animal on sense of smell. Each olfactory lobe encloses an extremely narrow cavity, the olfactory ventricle, which opens behind into the lateral ventricle of its side.

(*ii*) **Cerebral Hemispheres.** The cerebral hemispheres, collectively called **cerebrum**, are very large and form about two-third of the whole brain. They partly cover the olfactory lobes in front and completely overlap the diencephalon and the optic lobes behind. The two hemispheres are separated from each other by a deep longitudinal groove, the **median fissure**. The surface of each hemisphere is smooth save for two grooves or fissures : the **Sylvian and rhinal fissures**; which divide it into lobes. The Sylvian fissure lies obliquely at the outer side of each hemisphere and divides it into an anterior **frontal lobe**, posterior median **parietal lobe** and the postero-lateral **temporal lobe**. The rhinal fissure lies longitudinally on the ventral side of the hemisphere and separates a median **hippocampal lobe** from the frontal and temporal lobes. Though distinct to look at, the two hemispheres are intimately joined together by a transverse band of nerve fibres, the **corpus callosum**, which

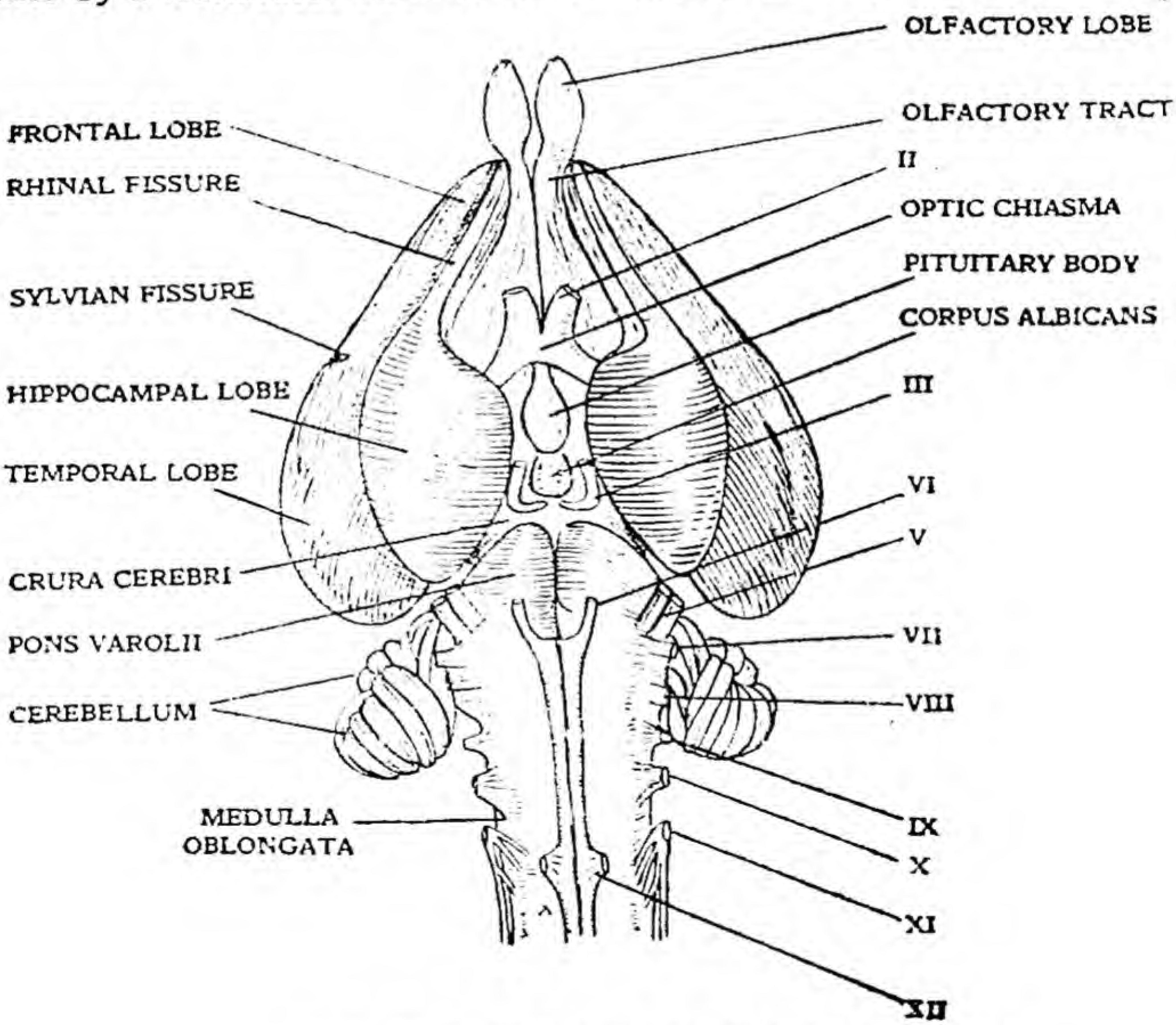


Fig. 21.3. The brain of rabbit (ventral view)
(I–XII cranial nerves)

can be seen by gently pulling the hemispheres apart. The hind end of the corpus callosum bends downwards and forwards to join another tract, the **fornix**, of longitudinal fibres. Bounded dorsally by the corpus callosum, ventrally by the fornix and laterally by the hemispheres is a space, the **pseudocoel** or **fifth ventricle**. It is to be noted that it is not a true ventricle, as it is not inside the brain. Each cerebral hemisphere

contains a narrow branching cavity, the **lateral ventricle** (Fig. 21.5). The roof and dorso-lateral wall of the lateral ventricle are thin and are called the **pallium** while its floor and ventro-lateral wall are thickened to form the **corpus striatum.** The two lateral ventricles communicate with each other and with the third ventricle by a transverse passage, the **foramen of Monro.**

(iii) **Diencephalon.** The diencephalon is quite small and lies beneath the cerebral hemispheres. It encloses a narrow laterally-compressed cavity, the **third ventricle.** The lateral walls of the third ventricle are greatly thickened and are called the **optic thalami.** Its roof is thin, vascular and non-nervous. It consists of an epithelium covered by vascular piameter. The two layers are fused and are together called **tela choroidea.** Vascular folds of tela choroidea project into the third ventricle to form the anterior **choroid plexus.** The latter extends into the lateral ventricles. A slender outgrowth, called the **pineal stalk,** arises from the roof of the third ventricle, extends backwards and ends in a small rounded structure, the **pineal body.** On the floor of the third ventricle is a funnel-like depression, the **infundibulum**, which bears the **pituitary body** below. A small rounded body, the **corpus albicans or corpus mammillare,** is attached to the ventral side of the diencephalon behind the pituitary body. The **optic chiasma** or the crossing of the two optic nerves is found in front of the pituitary body.

(b) **Mid-brain.** The mid-brain produces two parts : **optic lobes** on the dorsal side and **crura cerebri** on the ventral side.

(i) **Optic Lobes.** The optic lobes are also hidden beneath the cerebral hemispheres. A transverse groove divides each optic lobe into two parts : the anterior larger and the posterior smaller. The four

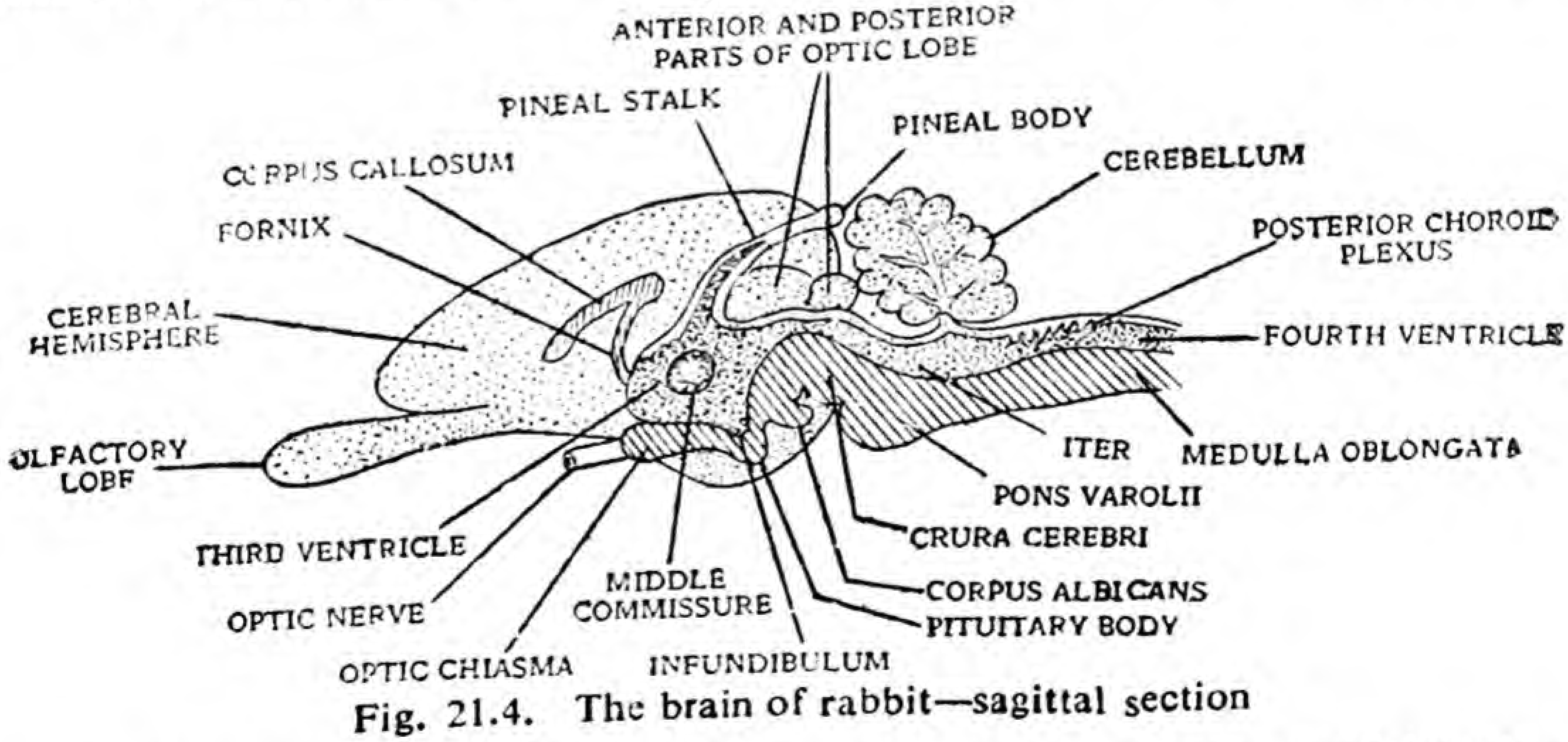


Fig. 21.4. The brain of rabbit—sagittal section

parts, thus formed, are collectively called the **corpora quadrigemina.** The anterior and posterior pair are respectively called the **superior** and **inferior colliculi.** The optic lobes are almost solid.

(ii) **Crura Cerebri.** The crura cerebri are two thick bands of nervous

tissue running antero-posteriorly below the **optic** lobes and linking the diencephalon with the hind-brain.

(*c*) **Hind-brain.** A dorsal projection from the anterior end of the hind-brain develops into the **cerebellum** while the remainder of the hind-brain becomes **medulla oblongata**. The floor of the cerebellum thickens into **pons varolii**.

(*i*) **Cerebellum.** The cerebellum, like the cerebrum, is a very large and well-developed part of the brain. It projects forwards to meet the cerebral hemispheres and also extends laterally. It is differentiated into five lobes : a large median lobe called the **vermis**, two small **lateral lobes** on the sides of the vermis, and two still smaller **floccular lobes** outside the lateral lobes. The surface of the cerebellum is thrown into numerous folds, the **gyri**, separated by deep grooves, the **sulci.** The cerebellum is solid. Its section shows a tree-like pattern of branching lines, the **arbor vitae.**

(*ii*) **Medulla Oblongata**. The medulla oblongata is the posteriormost part of the brain. It is broad in front but tapers behind to pass insensibly into the spinal cord. It encloses a wide cavity, the **fourth**

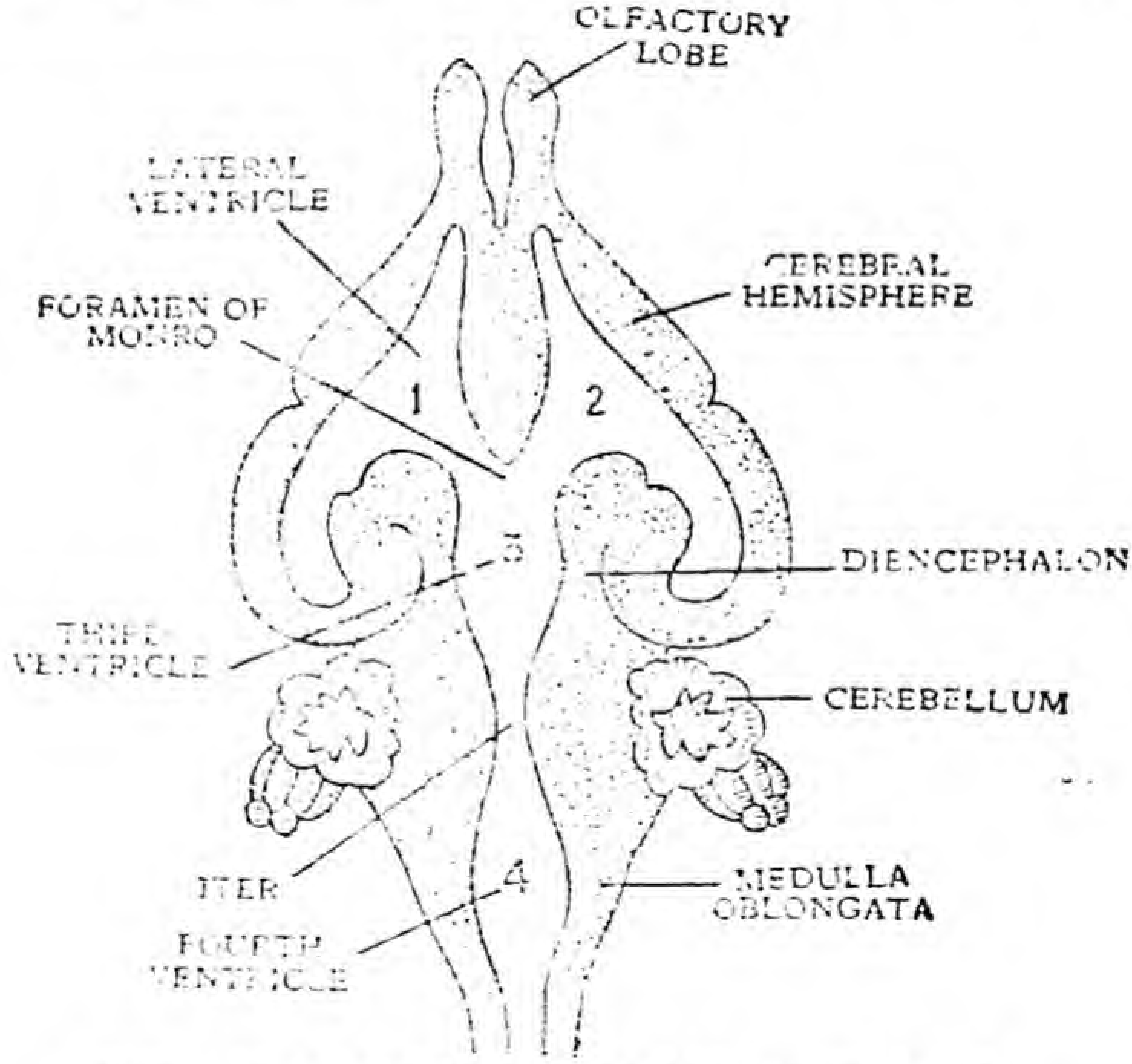


Fig. 21.5. Brain of rabbit in longitudinal horizontal section showing ventricles.

ventricle. A narrow median longitudinal passage, the **iter**, extends through the mid-brain and connects the fourth ventricle with the third ventricle. The roof of the fourth ventricle is thin, vascular **and** non-nervous. It is called **tela choroidea** and consists of an **epithelium fused** with piamater. Its vascular folds project into the fourth ventricle **as the posterior choroid plexus.**

(*iii*) **Pons Varolii.** The pons varolii is a transverse band of nerve fibres running across the ventral surface of the medulla oblongata and connecting the two sides of the cerebellum.

All the ventricles of the brain are continuous and contain a lymph-like fluid, termed the **cerebrospinal fluid**. This fluid is secreted by the anterior and posterior choroid plexes.

The sides of the brain are connected at many places by bands of fibres called the **commissures**. Of these, the corpus callosum which connects two halves of the cerebrum and pons varolii which connects two sides of the cerebellum are very evident and have already been mentioned. Others are not visible in the undissected brain. These include the **anterior commissure** connecting the corpora striata, the **middle commissure** between the optic thalami, the **posterior commissure** joining the two anterior corpora quadrigemina, and the **hippocampal commissure** between the two hippocampal lobes.

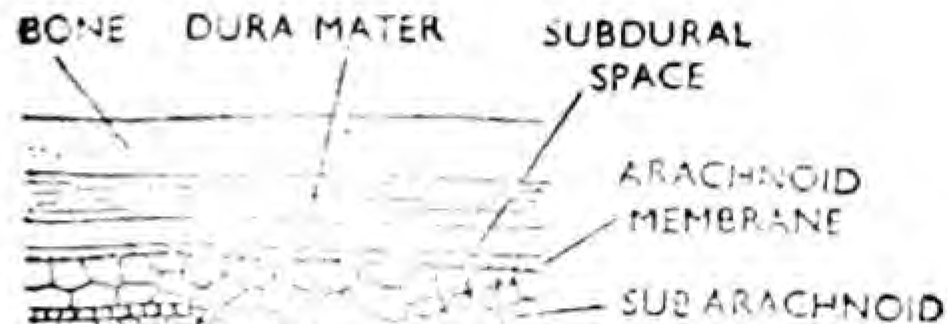


Fig. 21.6. Meninges of the brain.

Histology. The brain is composed of two types of nervous matter : **grey matter** consisting of nerve cells and **white matter** made up mainly of nerve-fibres, the fatty sheaths of which give it its white appearance. In the olfactory lobes, cerebral hemispheres, diencephalon and cerebellum, the grey matter is external and white matter internal. In the optic lobes and medulla oblongata the arrangement is reverse, *i.e.* white matter is external and grey matter internal. In the cerebellum, the internal white matter has the form of a branching tree, the **arbor vitae** (already referred to).

Meninges. The brain is surrounded by three membranes (Fig. 21.6) known as the **meninges** (singular **meninx**). The inner meninx is very thin and highly vascular. It closely invests the brain. It is called the **pia mater**. The middle meninx is also thin and vascular. It is termed the **arachnoid membrane**. There is a narrow space between the pia mater and the arachnoid membrane. It is called the **subarachnoid** space. It contains cerebrospinal fluid and is traversed by connective tissue strands. The outer meninx is quite thick and tough. It lines the cranial cavity and is named **dura mater**. A narrow space also exists between the dura mater and the arachnoid membrane. It is called the **subdural space**. It also contains the cerebrospinal fluid. The cerebrospinal fluid is secreted into the ventricles of the brain by the choroid plexes. It passes out into the subarachnoid space through three openings in the roof of the medulla oblongata. From the subarachnoid space, it is absorbed by the blood vessels of arachnoid membrane. The cerebrospinal fluid, thus, ultimately goes into the venous system.

Functions. The olfactory lobes are concerned with the sense of smell. As the rabbit locates its food mainly by sight, its olfactory lobes

are relatively small in size. The cerebral hemispheres receive sensory impulses from the sense organs and initiate motor impulses for voluntary movements. They are also the seat of intelligence, memory, will and emotions. These faculties are poor in rabbit as the surface of the hemispheres is almost smooth. The diencephalon acts as a relay station in conveying the impulses to the cerebrum and as integrating centre of the autonomic nervous system. It also perceives some crude sensations like extremes of heat, cold, pain, etc. The superior colliculi contain receptive centres of the sense of sight and the posterior colliculi serve to integrate auditory impulses. The crura cerebri carry sensory impulses from the medulla oblongata and the spinal cord to the optic thalami and thence to the pallium. The cerebellum maintains equilibrium and coordinates the voluntary movements. It is well developed in rabbit as it performs a wide range of active movements. The medulla oblongata controls the involuntary movements like those of internal organs.

2. Spinal Cord (Fig. 21.7)

Morphology. The spinal cord is a long, whitish, tubular structure situated in the neural canal of the vertebral column (Fig. 15.1). It develops from the posterior narrow part of the neural tube of the embryo (Fig. 21.1). It extends from the medulla oblongata to the lumbar region where it narrows into a slender non-nervous thread called the **filum terminale.** It shows little differentiation except that it is slightly flattened dorso-ventrally and is somewhat thickened in the region of fore- and hind-limbs to form the **brachial** and **sciatic swellings.** All along its mid-ventral

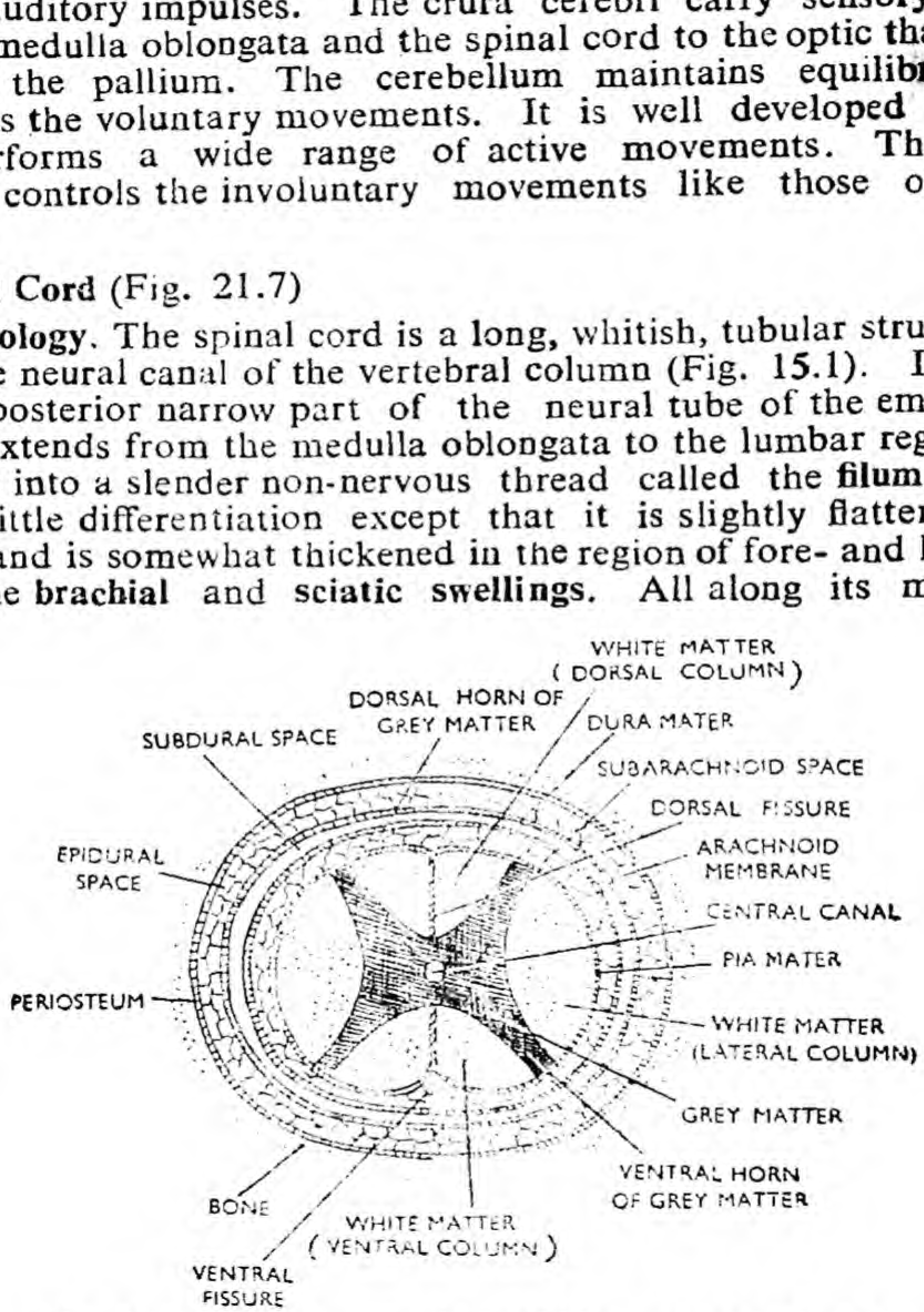


Fig. 21.7. The spinal cord of rabbit—transverse section.

line, the spinal cord has a deep groove, the **ventral fissure.** A very shallow depression, the **dorsal fissure,** likewise extends along the

mid-dorsal line of the entire cord. It marks the line along which the folds of the neural tube fuse during development of the nervous system and is indicated in the thickness of the cord by a thin septum of connective tissue. The spinal cord encloses in it a narrow longitudinal cavity, the **central canal**, lined by an epithelium. The central canal opens in front into the fourth ventricle of the brain but is closed behind. It is filled with the cerebro-spinal fluid.

Histology. Like the brain, the spinal cord is also composed of two types of nervous tissue : **grey matter** and the **white matter**. The grey matter is internal, *i.e* surrounds the central canal. It has the form of a rectangle whose angles are drawn into **dorsal** and **ventral horns or cornua.** It consists mainly of nerve-cells and non-medullated nerve-fibres, hence its grey colour in the fresh cord. The horns of the grey matter are continued into the roots of the spinal nerves. The white matter is outside the grey matter. It consists mainly of the medullated nerve-fibres, the fatty sheaths of which give it white appearance in the fresh cord. The white matter is divided by the horns of the grey matter into three columns on either side : the **dorsal lateral** and **ventral columns.**

Meninges. All the three meninges (pia mater, arachnoid membrane and dura mater) covering the brain are continued over the spinal cord. They likewise enclose the subarachnoid and subdural spaces containing the cerebo-spinal fluid. The dura mater, however, does not line the neural canal so that there is an additional space, the **epidural space,** between it and the bony wall of the neural canal. This cavity contains fatty and connective tissues and veins.

Functions. The spinal cord conducts the sensory and motor impulses to and from the brain. It is also a centre for the spinal reflex actions.

II. PERIPHERAL NERVOUS SYSTEM

The peripheral nervous system consists of nerves which connect the central nervous system with the sense organs and muscles of the body. These nerves can be classified into two categories according to their place of origin, namely, the **cerebral or cranial nerves** which arise from the brain and the **spinal nerves** which start from the spinal cord. Regarding their functions, the nerves can be divided into three groups : the **sensory** or **afferent nerves** which carry the sensory impulses from the sense organs to the central nervous system ; **motor** or **efferent nerves** which bring the impulses of motion from the central nervous system to the muscles, and the **mixed nerves** which carry the sensory impulses to and motor impulses from the central nervous system.

1. Cerebral Nerves

There are twelve pairs of cerebral nerves in rabbit. They leave the cranium through apertures or foramina in its wall and mainly innervate the different parts of the head alone.

1. The first pair of cerebral nerves are called the **olfactory nerves.**

They arise from the olfactory lobes and supply the sensory epithelium of the nasal chambers. They are sensory in nature.

2. The second pair of nerves, called **optic nerves**, arise from the floor of the diencephalon in front of the infundibulum. The two optic nerves cross each other to form the **optic chiasma**. They innervate the retina of the eyes. They are also sensory nerves.

3. The third pair or the **oculomotor nerves** originate from the corpus albicans. They are distributed to four out of six eye muscles, namely, the inferior oblique, internal rectus, superior rectus and inferior rectus. They are motor in nature.

4. The fourth pair of nerves, known as the **pathetic or trochlear nerves**, start from the dorsal side of the brain just behind the corpora quadrigemina and go to the fifth or superior oblique muscle of the eyeball. They are also motor nerves.

5. The fifth pair or the **trigeminal nerves** are large nerves and arise from the sides of anterior part of medulla oblongata. Soon after its origin, each nerve enlarges into a ganglion, the **Gasserian ganglion**, and then divides into three branches : (*i*) **ophthalmic branch** which supplies the skin of the snout and is sensory in nature, (*ii*) **maxillary branch** which supplies the palate, teeth of the upper jaw and the vibrissae and is also sensory in nature and (*iii*) **mandibular branch** which supplies the teeth and muscles of the lower jaw and the tongue. It is mixed in nature. The trigeminals are, thus, on the whole, mixed nerves.

6. The sixth pair or the **abducent nerves** begin from the floor of the medulla oblongata close to the median line and are spread over the sixth or external rectus muscles of the eyeballs. They are motor in nature.

7. The seventh pair or the **facial nerves** are again large nerves. They commence from the sides of the medulla oblongata. Each divides into three branches : (*i*) the **palatine branch** to the roof of the buccal cavity, (*ii*) **chorda tympani** to the salivary glands and (*iii*) the **hyomandibular branch** to the muscles of the face, hyoid apparatus and the lower jaw. The facials are on the whole mixed nerves.

8. The eighth pair or the **auditory nerves** arise from the sides of the medulla oblongata and proceed to the internal ear. They are sensory nerves.

9. The ninth pair or the **glossopharyngeal nerves** take their origin from the sides of the medulla oblongata and are distributed to the tongue and the pharynx. They are mixed nerves.

10. The tenth pair or the **vagus (pneumogastric) nerves** are very large in size. They arise from the sides of the medulla oblongata. After leaving the cranium, each vagus nerve bears a ganglion, the **vagus ganglion**, which gives rise to three nerves : a short **anterior laryngeal** that runs inwards to supply the larynx ; a long **cardiac depressor** that runs backwards to supply the heart ; **main vagus** that runs backwards

to supply the heart, lungs and stomach. Near the heart, the main vagus sends one branch, the **recurrent laryngeal**, forwards to the larynx. The vagus nerves are mixed in nature.

11. The eleventh pair or the **accessory spinal** nerves are formed from a number of nerve-fibres, some of which arise from the sides of the medulla oblongata and others from the spinal cord. The latter, *i.e.* spinal fibres, enter the cranium through the foramen magnum to unite with the former, *i.e.* cerebral fibres The accessory spinals are distributed to the neck muscles and are motor in nature.

12. The twelfth pair or the **hypoglossal nerves** arise from the ventral side of the medulla oblongata like the sixth pair. They supply the muscles of the tongue and are motor in nature.

2. Spinal Nerves

There are thirty-seven pairs of spinal nerves in rabbit. They are classified into eight pairs of cervical, twelve pairs of thoracic, seven pairs of lumbar, four pairs of sacral and six pairs of coccygeal nerves. Practically all the spinal nerves are similar in origin and distribution.

Origin. Each spinal nerve arises from the spinal cord by **two roots** ; the **dorsal** and **ventral**, which are prolongations of the dorsal and ventral horns of the grey matter respectively (Fig. 21.8). The dorsal root consists of sensory fibres and bears a ganglion on it. The ventral root is composed of motor fibres and has no ganglion. The two roots unite in the neural canal to form the spinal nerve which comes out through an intervertebral foramen. The first pair of spinal nerves leave the neural canal between the skull and the first vertebra and the succeeding nerves come out in front of the corresponding vertebrae through the invertebral foramina.

Distribution. Outside the neural canal, the spinal nerves divide and subdivide to supply their fibres to the skin and muscles of the body. All of them are, therefore, mixed in nature. A few spinal nerves, however, have a special distribution also. The third cervical nerve produces a special branch, called the **auricular nerve,** which supplies the pinna of the ear. Special branches from the fourth, fifth and sixth cervicals unite to form the **phrenic nerve** which innervates the muscles of the diaphragm. The posterior four cervical nerves, namely, the fifth, sixth, seventh and eighth, and the first thoracic nerve join to form the **brachial plexus** from which nerves proceed to the shoulder and the fore-limb. The posterior two or three lumbar nerves and the anterior two or three sacral nerves unite to form the **sciatic plexus** which sends nerves to the pelvis and the hind-limbs.

Since the spinal cord ends in the lumbar region, the lumbar and sacral nerves run backwards for a considerable distance within the neural canal before they come out through the corresponding intervertebral foramina. These nerves form a bundle which is called the **cauda equina** from its resemblance to the horse's tail.

TABLE 10
Summary of Cerebral Nerves of Rabbit

No.	Name	Origin	Distribution	Function	Nature
I	Olfactory	Olfactory lobes	Olfactory epithelium in the nasal chambers	Smell	Sensory
II	Optic	Floor of diencephalon in front of infundibulum	Retina of the eye	Sight	Sensory
III	Oculomotor	Corpus albicans	Four muscles of eye-ball (superior, internal and inferior recti and inferior oblique), iris, upper lid and lens.	Movement of eyeball, iris upper lid and lens	Motor
IV	Pathetic (Trochlear)	Dorsal side just behind corpora quadrigemina	Superior oblique muscle of the eyeball	Rotation of eyeball	Motor
V	Trigeminal	Side of medulla	——	Touch, taste, and movement of chewing (jaw) muscles	Mixed
	(*i*) Ophthalmic	——	Skin of snout		
	(*ii*) Maxillary	——	Palate, teeth of upper jaw, vibrissae.		
	(*iii*) Mandibular	——	Teeth and muscles of lower jaw, taste buds of the tongue		
VI	Abducent	Ventral side of medulla	External rectus muscle of the eye-ball	Rotation of eyeball	Motor
VII	Facial	Side of medulla	——	Taste, face expression, mastication, movement of neck, stimulation of salivary glands	Mixed
	(*i*) Palatine	——	Palate		
	(*ii*) Chorda tympani	——	Salivary glands		
	(*iii*) Hyomandibular	——	Muscles of face, lower jaw, hyoid and neck		
VIII	Auditory	Side of medulla	Internal ear (organ of Corti and semicircular ducts)	Hearing and equilibrium	Sensory
IX	Glossopharyngeal	Side of medulla	Mucous membrane and muscles of pharynx; tongue, and parotid gland	Taste, movement of pharynx, secretion of saliva	Mixed
X	Vagus or Pneumogastric	Side of medulla	——	Visceral movement and sensation	Mixed
	(*i*) Anterior Laryngeal	——	Anterior side of Larynx		
	(*ii*) Cardiac depressor	——	Heart		
	(*iii*) Recurrent laryngeal	——	Posterior side of Larynx		
	(*iv*) Main vagus	——	Heart, lungs, stomach, oesophagus.		
XI	Spinal accessory	Side of medulla	Muscles of pharynx, larynx, shoulder and neck	Movement of pharynx, larynx, shoulder and neck	Motor
XII	**Hypoglossal**	**Floor of medulla**	**Muscles of tongue.**	**Movement of tongue.**	**Motor**

III. AUTONOMIC NERVOUS SYSTEM

The autonomic nervous system consists of two parts : the **sympathetic** and **parasympathetic**, which have antagonistic effects.

1. **Sympathetic Nervous System.** The sympathetic nervous system consists of a pair of long ganglionated cords which start anteriorly from the fifth cerebral nerves and extend posteriorly to the end of the body. They run alongside the common carotid arteries in the neck and beside the aorta in thorax and abdomen. Each cord bears two ganglia in the neck. These are called the **anterior cervical ganglion** situated near the larynx and the **posterior cervical ganglion** lying near the innominate artery. Each cord further bears twelve **thoracic ganglia** in the thorax and twelve **abdominal ganglia** in the abdomen. The thoracic and abdominal ganglia are connected with the spinal nerves by small nerves, the **rami communicantes**. These ganglia give off efferent nerves to the various viscera like the blood-vessels, heart, lungs, stomach, intestine, kidney, bladder, etc.

Nerves from a few posterior thoracic ganglia unite to form a large nerve, the **splanchnic nerve,** on either side. The two splanchnic nerves pierce the diaphragm and enter the abdomen where they join with a large **coeliac ganglion** situated in the mesentery just in front of the origin of the anterior mesenteric artery. The coeliac ganglion is connected behind with the **anterior mesenteric ganglion** lying behind the anterior mesenteric artery. Several nerves arise from these ganglia and supply the abdominal viscera. These ganglia and their nerves together form what is called the **solar plexus.**

Nerves from a few hinder abdominal ganglia likewise end in the **posterior mesenteric ganglion** lying just behind the origin of the posterior mesenteric artery from the aorta. This ganglion sends nerves to the rectum and the urinogenital organs. The posterior mesenteric ganglion and its nerves form the **posterior plexus.**

The sympathetic nervous system supplies the internal organs or the viscera only. The nerves arising from the ganglia of this system are all motor as they chiefly control the movements of the viscera. As the movements of the viscera are involuntary, the sympathetic nervous system may be said to control the **involuntary actions.**

2. **Parasympathetic Nervous System.** The parasympathetic nervous system consists of fibres from the brain as well as the spinal cord. Those from the brain come through the oculomotor (*iii*), facial (*vii*), glossopharyngeal (*ix*) and vagus (*x*) nerves while those from the spinal cord emerge by way of the II, III and IV sacral spinal nerves. These parasympathetic fibres innervate the same structures as the sympathetic, except the oviduct. The action of the parasympathetic fibres is opposite to that of the sympathetic fibres.

Reflex Action

Animals perform two types of actions : **voluntary** and **involuntary.**

The voluntary action is performed by the animal with its will. In this action the animal exercises free choice as a result of which the same stimulus may get different responses at different times, depending upon the situation. For instance, at the sight of a snake one may run away if unarmed and try to kill it if armed with a stick to save oneself. The involuntary action, on the other hand, is performed by the animal without its will. It is very quick and the animal has no choice in it. Consequently, the same stimulus always receives the same response just as in a machine pressing of a particular button results in the movement of a definite part of it. For example, the hand is withdrawn every time it is pinched suddenly. The involuntary actions are known as the **reflex actions.**

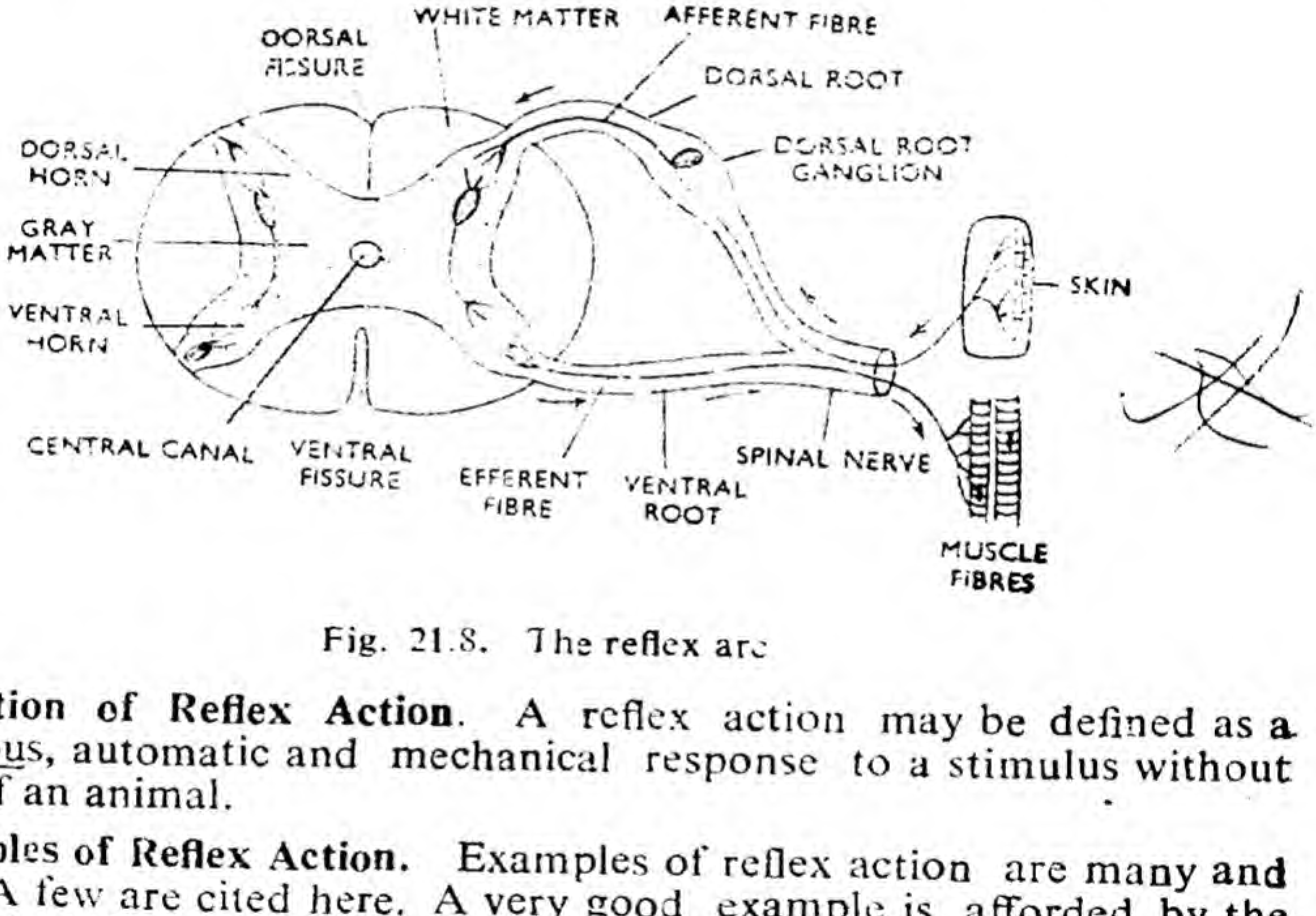


Fig. 21.8. The reflex arc

Definition of Reflex Action. A reflex action may be defined as a spontaneous, automatic and mechanical response to a stimulus without the will of an animal.

Examples of Reflex Action. Examples of reflex action are many and varied. A few are cited here. A very good example is afforded by the withdrawal of the leg in a decapitated frog when touched with an acid. Here the action of the frog does not at all involve the will as it is devoid of brain. Reflex actions are performed in the presence of the brain also, *e.g.* closing of the eyes if strong light is suddenly flashed on them. This reflex action, though performed without our will, is in our knowledge. There are many reflex actions which go on without our knowledge. A few reflex actions of this type are : flow of bile from the gall bladder into the duodenum when the food reaches there, peristalsis of the alimentary canal and beating of the heart.

Mechanism of Reflex Action. The reflex action is brought about in the following manner. The acid when applied to a toe of a decapitated frog stimulates the touch corpuscles of the skin. The touch corpuscles set up and send a sensory impulse to the spinal cord through the dorsal sensory root of a spinal nerve. The spinal cord transforms the sensory impulse into a **motor** impulse and transmits the latter to the leg

muscles through the ventral motor root of the spinal nerve. The muscles then contract to withdraw the leg.

The Reflex Arc. The path travelled by an impulse in a reflex action is called the **reflex arc** (Fig. 21.8). It consists of three parts :

(*i*) the **afferent nerve** which brings the sensory impulse from the sense organ to the central nervous system,

(*ii*) a **portion of the central nervous system**, brain or spinal cord, and

(*iii*) the **efferent nerve** which carries the motor impulse from the central nervous system to the muscles.

Importance of Reflex Action. Reflex action is very important. It confers a two-fold benefit on the animal. It enables the animal to respond to the harmful stimuli immediately so that no harm is caused to the animal. It relieves the brain of too much work as the responses of routine nature take the form of reflex actions. If the animal is to exercise its will every time a wave of peristalsis is started in the gut, the brain would soon be exhausted.

TEST QUESTIONS

1. What is the function of the nervous system ? Name the various types of nerves and show how they differ from each other.
2. Give a brief description of the brain of rabbit.
3. What is central nervous system ? Name the fluid found in and around the central nervous system. Write all you know about the spinal cord of rabbit.
4. Give an account of the cerebral nerves of rabbit.
5. Discuss the spinal nerves of rabbit.
6. Describe the sympathetic nervous system of rabbit.
7. Write notes on :—

Reflex action, Vagus nerve, Solar plexus, Diencephalon, Grey matter,

CHAPTER 22

Oryctolagus cuniculus

(The Rabbit)

SENSE ORGANS

The sense organs serve to make the animal aware of the various stimuli acting on the body externally or originating within the body itself. They perform this function with the assistance of the nervous system.

All sense organs resemble in their basic structure as well as in their mode of working. Every sense organ has a specially modified cell (or cells) known as the **receptor cell**. This cell receives the stimulus and initiates a nerve impulse. The latter is at once relayed by the sensory nerve to the brain, either directly or through the spinal cord. In the brain the impulse is interpreted as sensation and the animal comes to know of the impulse acting on the sense organ. The sense organs themselves are unable to interpret the impulses generated by the stimuli. They merely serve as a means of access to the nervous system. Actually speaking, therefore, the animals feel, taste, smell, see and hear with the brain. Of course, the brain without sense organs is of no importance.

The receptor cells occur almost everywhere in the body. They are of many types and give rise to diverse sensations. They fall into two main categories : the **external receptors** or **exteroceptors** and the **internal receptors**. The external receptors are stimulated by changes in the environmental factors and make the animal aware of these changes. They form the popular sense organs, namely, the organs of touch, taste, smell, sight and hearing. The internal receptors are affected by stimuli originating within the body itself and cause sensations like pain, hunger, thirst, fatigue, sex, muscle position, etc. They mostly consist of free nerve endings. They are called **enteroceptors** when they lie in the alimentary canal and **proprioceptors** when they occur in the muscles, tendons, joints, heart and other areas.

I. Organs of Touch (Tangoreceptors)

The receptors of touch and pressure are nerve endings of three types: free, basket and encapsulated (Fig. 22.1).

(1) **Free Nerve Endings**. These are fine branching fibres from sensory nerve cells, terminating in the superficial layers of the dermis and even extending into the epidermis. These occur in the hair-covered parts of the body.

(2) **Basket Nerve Endings.** These are fine branching fibres of sensory nerve cells wrapped round the hair follicles, forming basket work. These also occur in the hairy parts of the body.

(3) **Encapsulated Nerve Endings.** These comprise nerve fibres in the dermis surrounded by a sheath of connective tissue. These are found in the hairless regions.

Contact of any object with the skin or hair stimulates the nerve endings which set up nerve impulses. The latter are transmitted by nerves to the thalamus and probably to the cerebral hemispheres where the actual sensation is felt.

The skin also has receptors for perceiving heat, cold and pain.

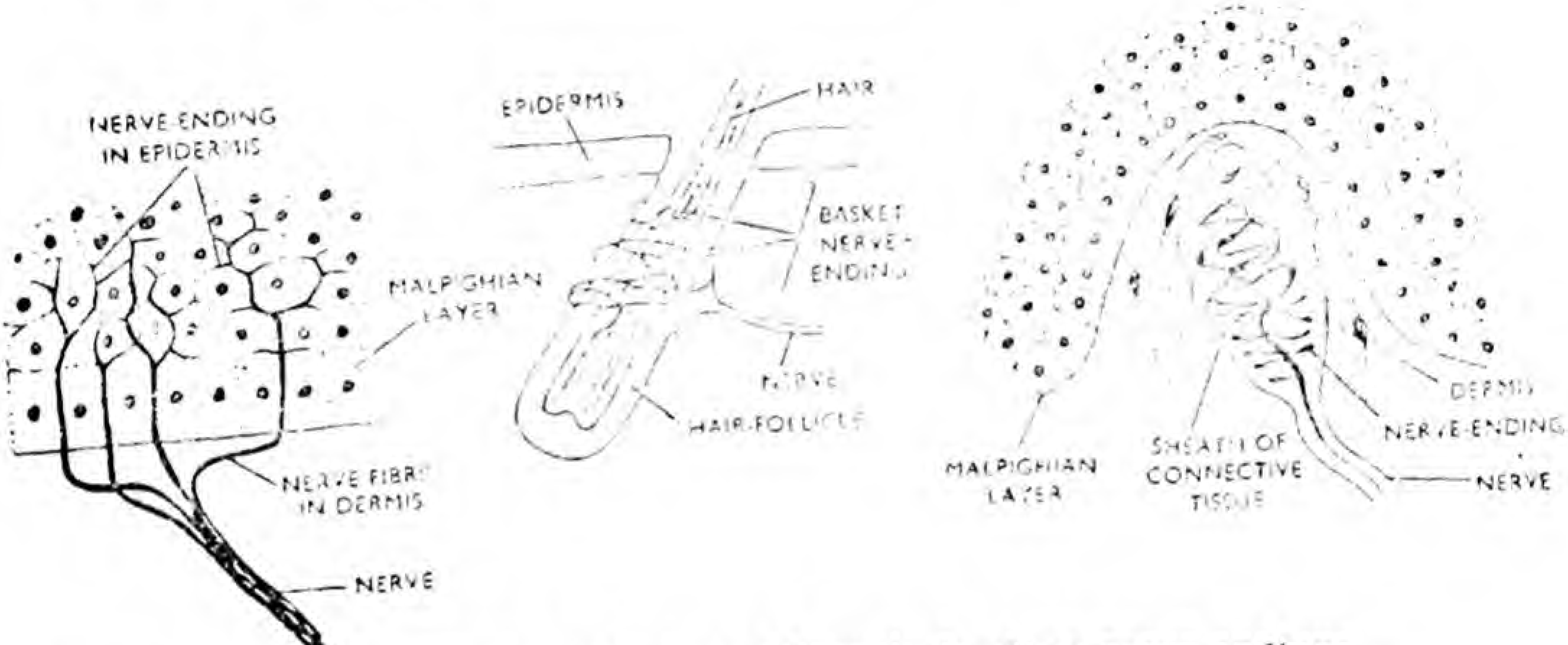


Fig. 22.1. Skin receptors or organs of touch A—Free nerve endings B—Basket nerve ending C—Encapsulated nerve ending

II. Organs of Taste (Gustatoreceptors)

The receptor organs for taste are the **taste buds** (Fig. 22.2) situated on papillae of the tongue and on the soft palate. Each taste bud consists of a group of long narrow cells, the **taste cells**, surrounded by cylindrical supporting cells. A taste cell has a small hairy projection on the free end to come in contact with the food being eaten. Its other end is connected with fibres of the nerves of taste. The taste cells are sensitive to chemicals in solution which is formed in the mucus covering them. They transform the chemical stimuli into nerve-impulses which are carried to the thalamus and thence to the cerebrum where the sensation of taste arises.

III. Organs of Smell (Olfactoreceptors)

The organs of smell are the upper parts of the **nasal chambers.** The ethmoturbinals in this part of the nasal chambers are covered with **olfactory epithelium,** which consists of spindle-shaped **olfactory cells** and columnar **supporting cells** (Fig. 22.3). Each olfactory cell bears a number of fine, non-motile, hair-like processes at its free end and its other end continues as a nerve-fibril which joins the olfactory nerve.

Like the taste cells, the olfactory cells are also stimulated by chemical substances in solution which is formed in the watery mucus covering them. The mucus is secreted by special mucous glands present in the olfactory epithelium. An important difference from the taste cells is that the olfactory cells are stimulated by chemicals from a distance and in much lower concentration. The chemical vapours emanating from

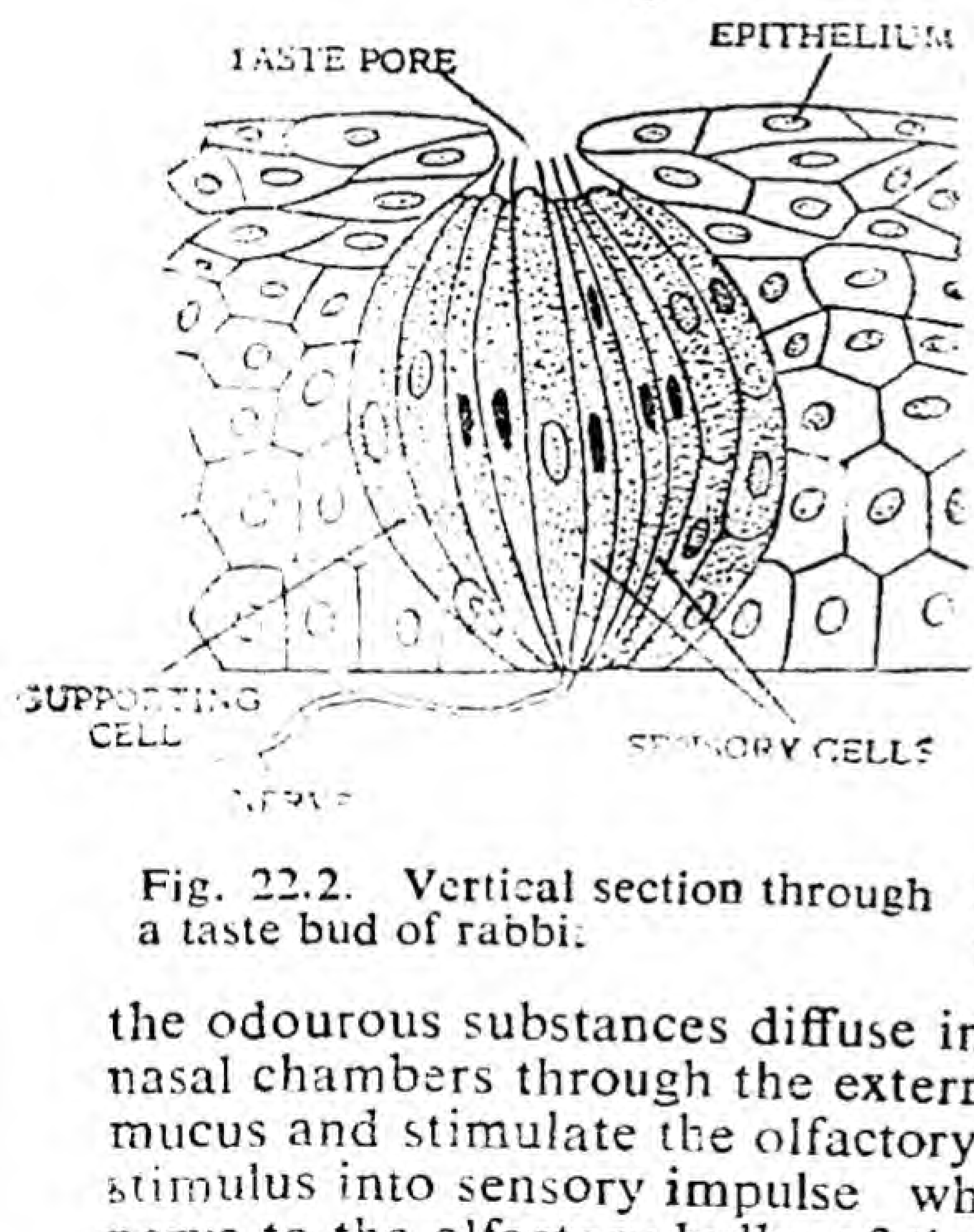


Fig. 22.2. Vertical section through a taste bud of rabbit.

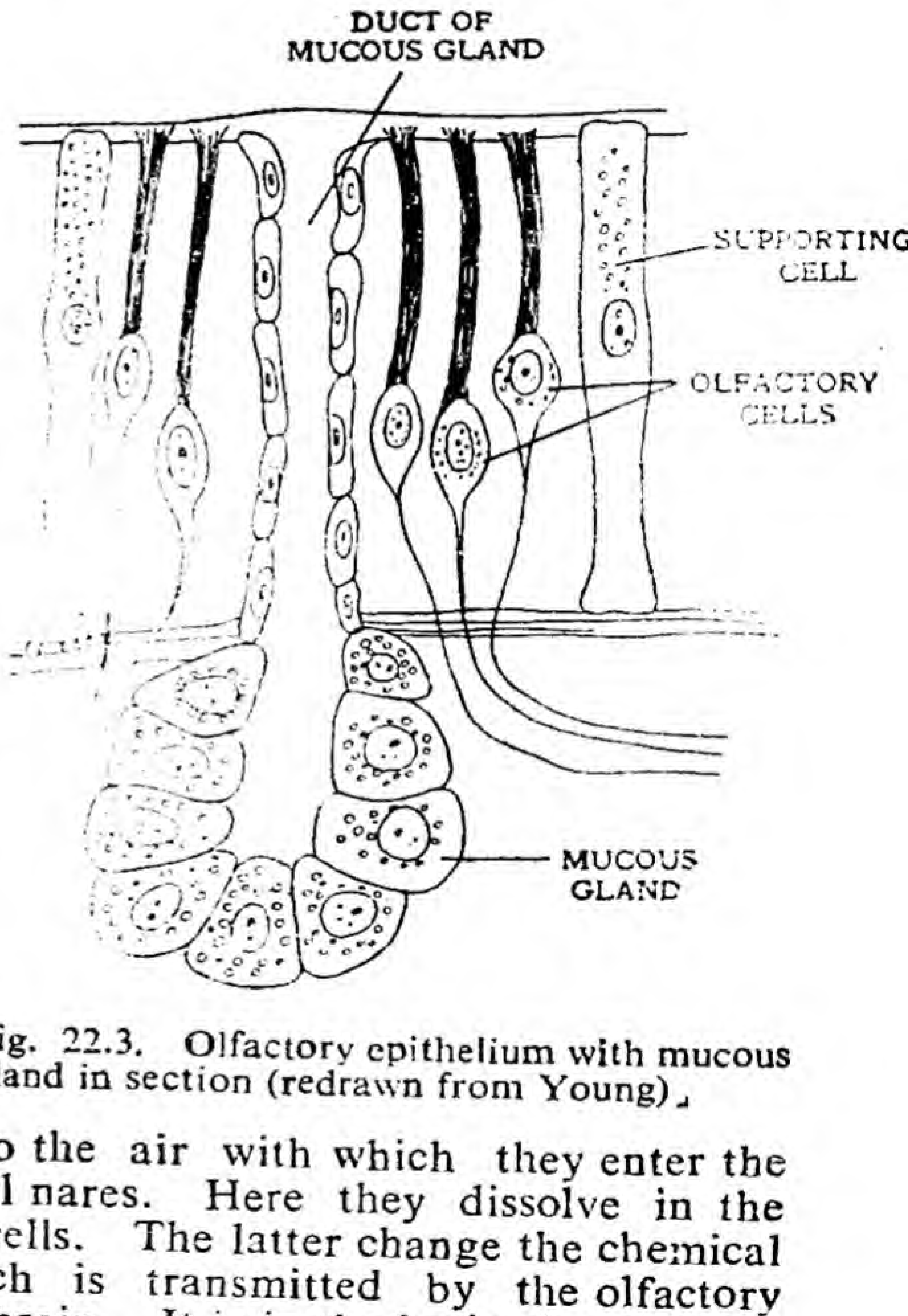


Fig. 22.3. Olfactory epithelium with mucous gland in section (redrawn from Young).

the odourous substances diffuse into the air with which they enter the nasal chambers through the external nares. Here they dissolve in the mucus and stimulate the olfactory cells. The latter change the chemical stimulus into sensory impulse which is transmitted by the olfactory nerve to the olfactory bulbs of the brain. It is in the brain that the real sensation of smell arises. The sense of smell is useful not only in locating food but also for determining the presence of enemies and for finding out the mate.

IV. Organs of Sight (Photoreceptors)

The organs of sight are a pair of eyes. They are situated in the eye-sockets or orbits and are only partly visible from outside.

Structure. The eyeball is roughly spherical in form. Its wall is composed of three layers or coats. Beginning from outside, these coats are named fibrous tunic, urea and retina. Of these, the fibrous tunic alone is complete. Others are incomplete anteriorly.

1. **Fibrous Tunic.** The fibrous tunic is the outermost coat of the eye-ball. It is quite thick and tough. It protects the eyeball and maintains its form. It has two distinct regions : a larger, posterior, opaque, whitish part, the **sclerotic**, and a smaller, anterior, transparent, exposed part, the **cornea.** The sclerotic is composed of a dense fibrous connective tissue and is largely hidden in the orbit. A small portion of it is, however, visible externally. This is commonly called the "white" of the eye. All the muscles that move the eye are inserted over the

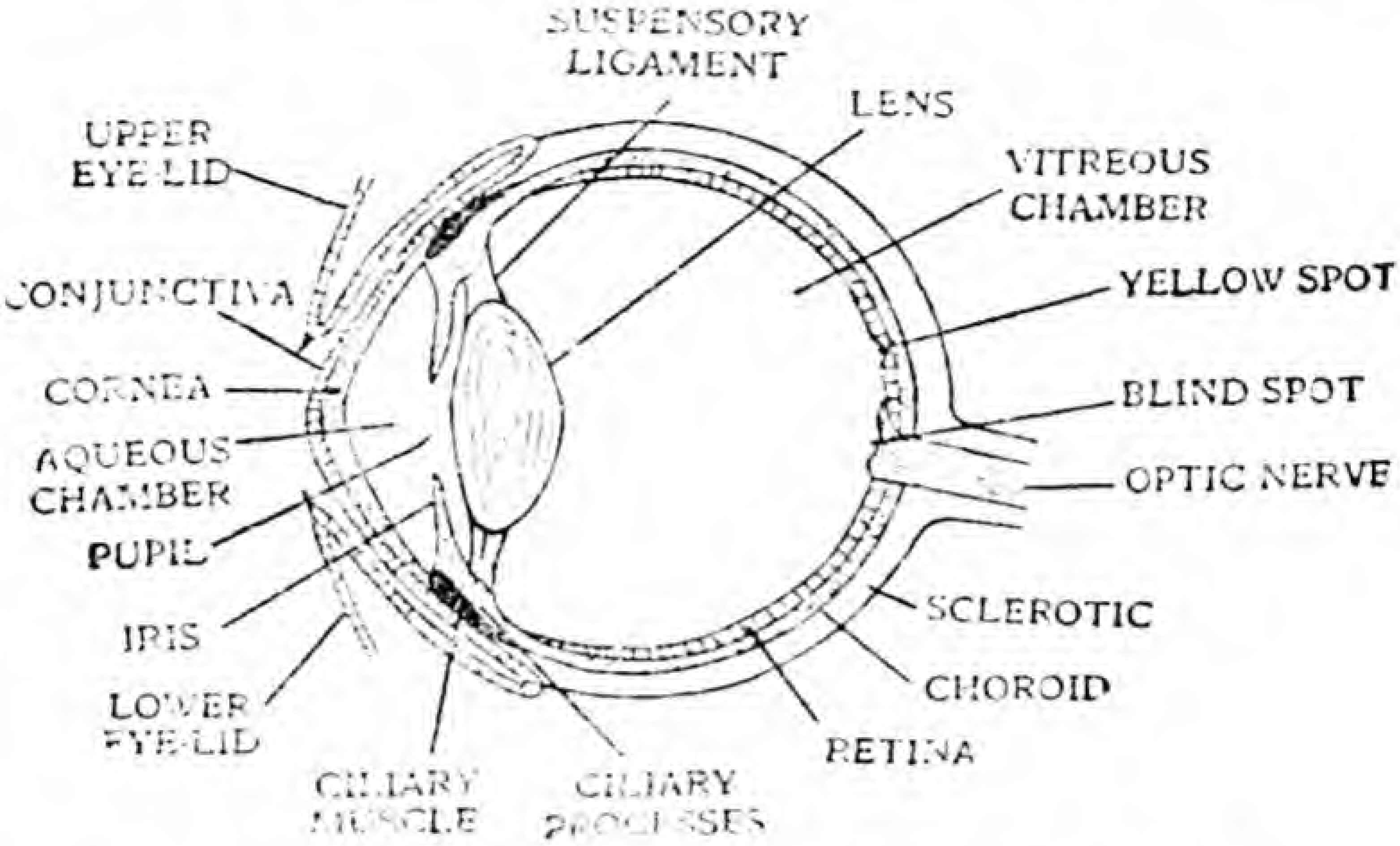


Fig. 22.4. Vertical section of the mammalian eye

sclerotic. The cornea is composed of a peculiar variety of connective tissue. It is covered externally by a thin transparent epithelial layer, the **conjunctiva,** which is continuous with the inner lining of the eyelids. The conjunctiva is fused with the cornea. The cornea lacks blood vessels and is nourished by lymph from adjacent areas. The cornea is thicker than the sclerotic and is slightly bulged anteriorly. Its curved surface assists the lens in focusing light rays.

2. **Uvea.** The uvea is the middle coat of the eyeball. It shows three regions. Its greater part lines the sclerotic and is known as the **choroid.** The latter is composed of a soft connective tissue with abundant pigment cells and blood-vessels. Being dark-brown in colour, the choroid serves to darken the cavity of the eyeball to prevent internal reflection of light. It perhaps also absorbs stray and excess light. At the junction of the sclerotic and the cornea, the uvea abruptly bends into the cavity of the eyeball to form the anterior surface of a thin coloured partition, the **iris.** The iris is perforated by an aperture, the **pupil,** and contains two sets of smooth (involuntary) muscle fibres : **sphincter** and **dilator muscles.** These muscles regulate the amount of light entering the eyeball by varying the size of the pupil. The contraction of the sphincter muscles, which are arranged in rings, makes the pupil smaller while that of the dilator muscles, which are disposed in a radial manner, dilates it. The degree of pigmentation in the iris gives characteristic colour to the eye. In albino rabbits,

there is no pigment in the iris whose blood-capillaries give the eye its pink colour. Just behind the peripheral margin of the iris, the uvea becomes thicker, less vascular, and less pigmented. This part of the uvea is called the **ciliary body.** The inner surface of the ciliary body is thrown into radiating folds, the **ciliary processes,** which project into the eyeball. The ciliary body contains the **ciliary muscles** which run both in a circular and meridional direction with respect to the eyeball. The meridional muscles are attached at their inner ends to the choroid and at their outer ends to the point where the sclerotic meets the cornea.

3. **Retina.** The retina is the innermost coat of the eyeball. It is a very delicate coat and lines the whole of the uvea. Like the uvea, it also shows three regions. These are called the **optic, ciliary** and **iridial parts.** The optic part of the retina is in contact with the choroid. It is thick and sensitive to light. Detailed microscopic structure of this part of the retina is given in chapter five. The ciliary and iridial parts are thin and non-sensory. They are in contact with the ciliary body and the iris respectively. The ciliary body and the iris are, thus, composed partly of the uvea and partly of the retina. A small area of the optic part of the retina lying exactly opposite the centre of the cornea is called the **area centralis** or **macula lutea** or yellow **spot.** In the middle of the yellow spot is a shallow depression, the **fovea centralis,** which is the place of most distinct vision.

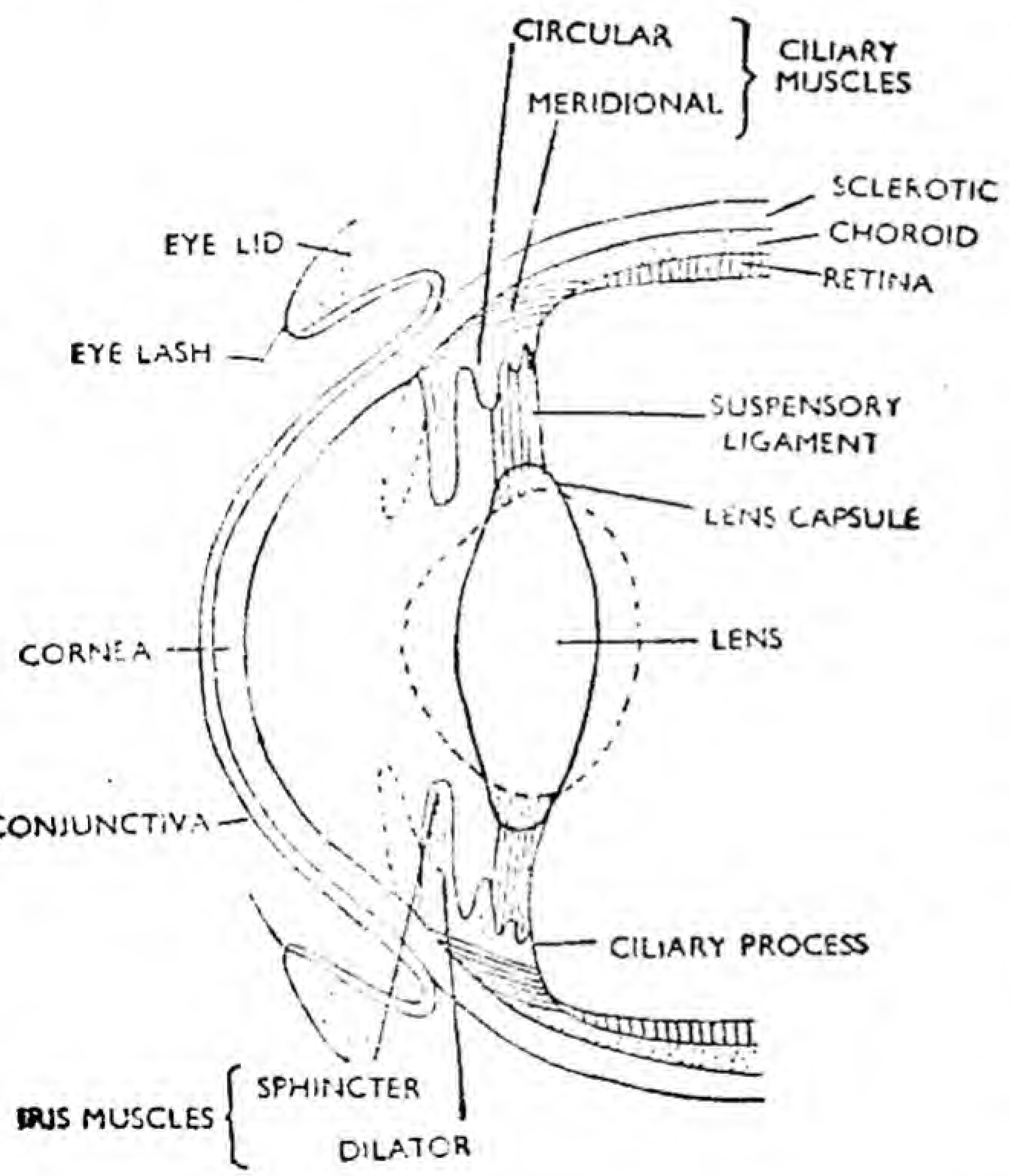


Fig. 22.5. Diagram showing changes during accomodation

The optic nerve leaves the eyeball from behind by piercing the eye coats. The point on the retina from where the optic nerve emerges is called the **blind spot** as it lacks the visual elements and is insensitive to light.

A transparent solid body, the **lens,** lies just behind the iris. It is enclosed in a thin transparent elastic membrane, the **lens capsule.** It is biconvex but more convex behind than in front. It is kept firmly in its place by a strong and elastic frame called the **suspensory ligament** which

extends from the capsule to the ciliary processes. The lens and its suspensory ligament divide the cavity of the eyeball into two chambers : the anterior smaller **aqueous chamber** and posterior large **vitreous chamber.** The aqueous chamber is partially divided by the iris into **anterior** and **posterior** parts. These parts are continuous with each other at the pupil. The aqueous and viterous chambers are filled with a clear watery **aqueous humour** and a thick, transparent, jelly-like **vitreous humour** respectively. The humours keep the eyeball taut and help in focussing light rays.

Protection. Eye has several protective devices. The movable eyelids, upper and lower, are closed to protect the delicate cornea. They are regularly closed at short intervals (blinking) to keep the cornea clean. The eyelids bear at their free margin a few stiff eyelashes which prevent the dust particles and rain drops from falling into the eyes. Opening into their follicles, the eyelashes have meibomian glands which produce a greasy substance for frictionless blinking. The third eyelid or nictitating membrane, which normally lies in the inner corner of the eye, can be moved sideways across the cornea when greater protection from dust or foliage is required. Situated in the orbit at the upper and outer region of the eyeball is a racemose **lacrymal gland** which secretes a slightly saline watery fluid. This lacrymal fluid (tears) serves many functions. It moistens the surface of the eyeball, nourishes the nonvascular cornea, washes the cornea and kills the bacteria. The excess of this secretion is drained away into the nasal chamber by way of the naso-lacrymal duct. A layer of fat surrounding the eyeball in the orbit serves as a soft shock-proof pad.

Movement Eyeball is rotated in the orbit by six strap-shaped muscles inserted on the sclerotic. These are arranged in two groups : **rectus** and **oblique**. The rectus group includes four muscles, namely, **superior rectus**, **inferior rectus**, **internal (medial) rectus** and **external (lateral) rectus**. These are inserted on the dorsal, ventral, inner and outer parts of the eyeball respectively and canverge to their point of origin in the postero-medial angle of the orbit. The oblique group comprises only two muscles, *i.e.* **superior oblique** and **inferior oblique**. These are inserted on the eyeball close to the superior rectus and inferior rectus respectively and converge to their point of origin at the anteromedial angle of the eyeball.

Working. The eye works more or less on the principle of a photographic camera. The conjunctiva, cornea, aqueous humour, lens, and vitreous humour all act as lenses to refract the rays of light entering the eye so as to bring them to a close focus on the retina. The retina receives an inverted and smaller image of the object lying in front of the eye. This image is carried by the optic nerve to the cerebral hemispheres of the brain where the real sensation of sight arises and the animal sees the object upright.

The eye of the rabbit possesses a good **power of accommodation,** *i.e.* it can adjust itself to distinctly see objects at varying distances. This is achieved by changing the convexity of the lens with the ciliary body

and suspensory ligament which form the accommodation apparatus. When focussed for seeing distant objects (those beyond 6 metres), the eye is said to be at rest. At this time, the ciliary muscles are fully relaxed, the suspensory ligament is under maximum tension (peripheral pull) and the lens is flattened. For focussing the eye on near objects (those within 6 metres), the convexity of the lens is increased by reducing the tension in the suspensory ligament. The tension in the ligament is reduced by contraction of the ciliary muscles, both circular and meridional, of the ciliary body. Contraction of circular muscles shortens the radius of the suspensory ligament, thus making it loose. The contraction of meridional muscles pulls the choroid forwards, suspensory ligament allows the lens to shorten its diameter by its own elasticity, thus, becoming thicker and more convex. The thickening of the lens shortens its focal length and adjusts it to focus the near objects. Reverse occurs to see objects at greater distances.

Eye of Sheep. Owing to its large size, the eye of sheep or goat is dissected in the laboratory for studying the anatomy of mammalian eye. It differs little from that of rabbit. A dissected eye is shown in the figure 22.6.

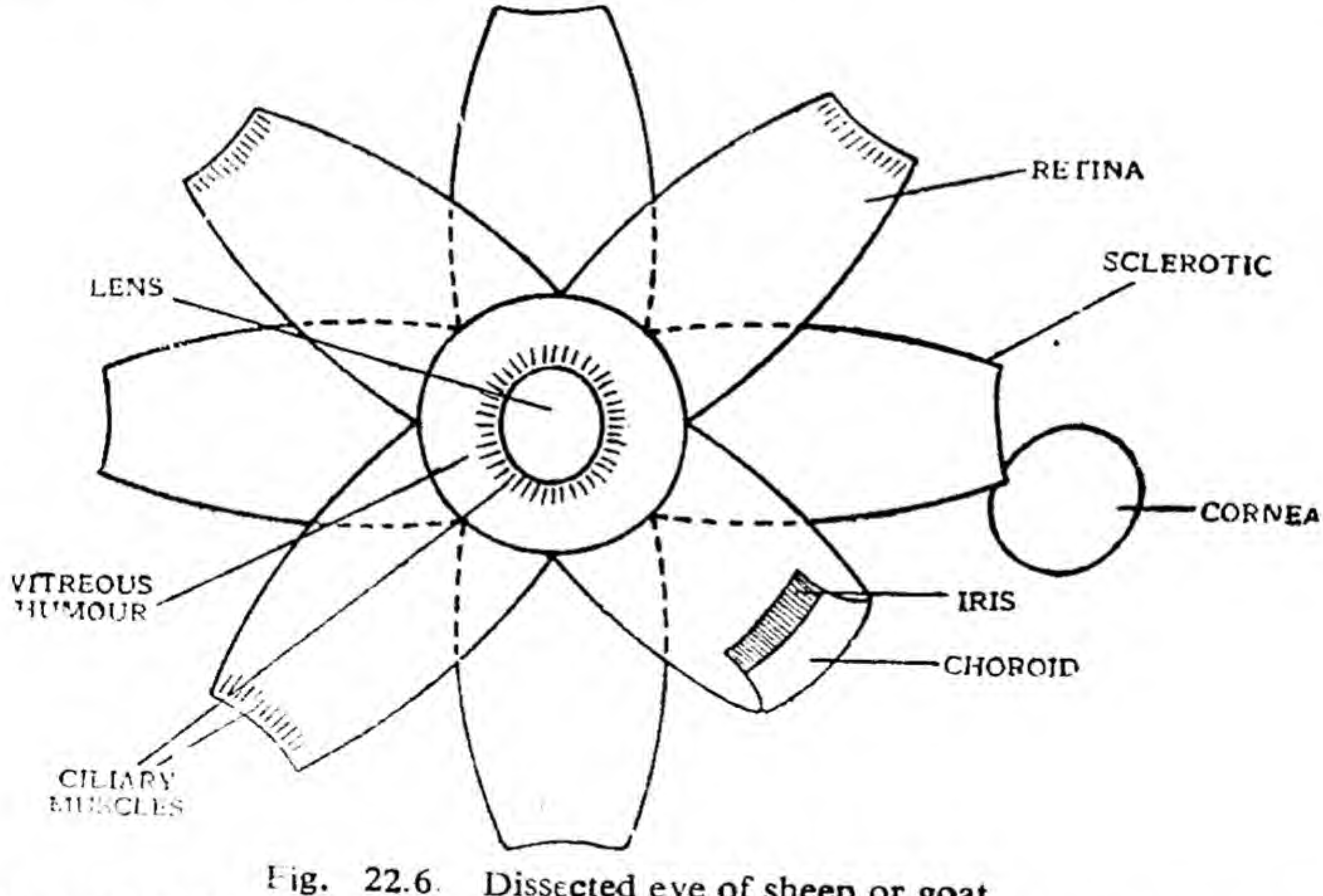


Fig. 22.6. Dissected eye of sheep or goat

V. Organs of Hearing (Phonoreceptors) and Equilibrium (Statoreceptors)

The organs of hearing and equilibrium are a pair of ears. These are situated, one on either side of the head, a short distance above or behind the eyes.

Structure. An ear (Fig. 22.7). consists of three parts : **external ear, middle ear and internal ear.**

1. **External Ear.** The external ear has two regions : **pinna or auricle**

and **external auditory meatus.** The pinna is a large, movable, trumpet-shaped structure that projects upwards from the side of the head. It is supported by elastic cartilage. It encloses a large cavity called the **concha.** The pinna serves to collect the sound waves. The meatus is a long tubular passage leading inwards from the concha. It is supported by cartilage in the outer part and by bone in the inner part. It is lined with skin continuous with that lining the concha and covering the pinna. The outer region of the meatus bears **hair** to keep out the dust. Further inside, it has **ceruminous** or **wax glands** which secrete a fatty substance, the **earwax** or **cerumen**. The latter lubricates and protects the tympanic membrane. The tympanic membrane is a thin, tightly stretched membrane closing the meatus internally. It is also called the **ear-drum**.

2. **Middle Ear.** The middle ear is constituted by an irregular air-filled cavity, the **tympanic cavity,** present in the **tympanic bulla**. It is lined by mucous membrane and communicates with the pharynx by means of a passage called the **Eustachian tube** which is directed forwards, downwards and inwards. The pharyngeal opening of the Eustachian tube remains closed except during swalloing, yaning and shouting when air enters or leaves the tympanic cavity to equalise the air pressure on the two sides of the tympanic membrane. Inner wall of the tympanic cavity is formed by the bony auditory capsule and has two

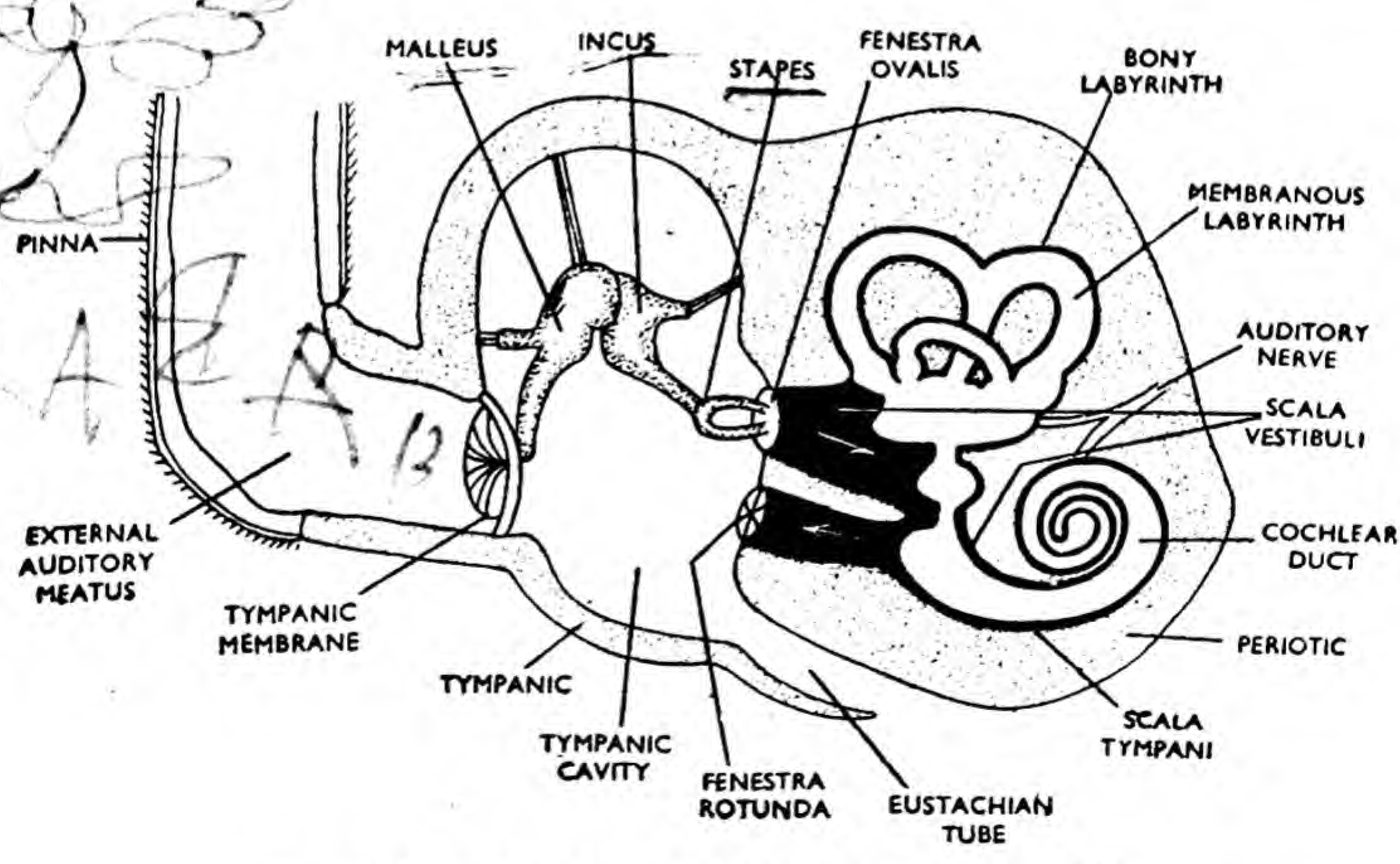


Fig. 22.7. T.S. **Head of rabbit through the ear**

apertures which put it in communication with the internal ear. Of these, the upper is called the **fenestra ovalis** or **oval window** and the lower **fenestra rotunda** or **round window.** Both these windows are closed by a membrane. The tympanic membrane is connected with the fenestra ovalis

by a chain of three small movably-articulated bones, the **ear ossicles**, that stretch across the tympanic cavity. Of these, the outer is hammer-shaped and is called the **malleus.** It is attached to the inner surface of the tympanic membrane. The middle is anvil-like and is called the **incus**. The inner resembles the stirrup in shape and is known as the **stapes.** It is attached to the membrane covering the **fenestra ovalis.**

3. **Internal Ear.** The internal ear (Fig. 22.8) consists of a complicated structure called the **membranous labyrinth.** It is enclosed by a

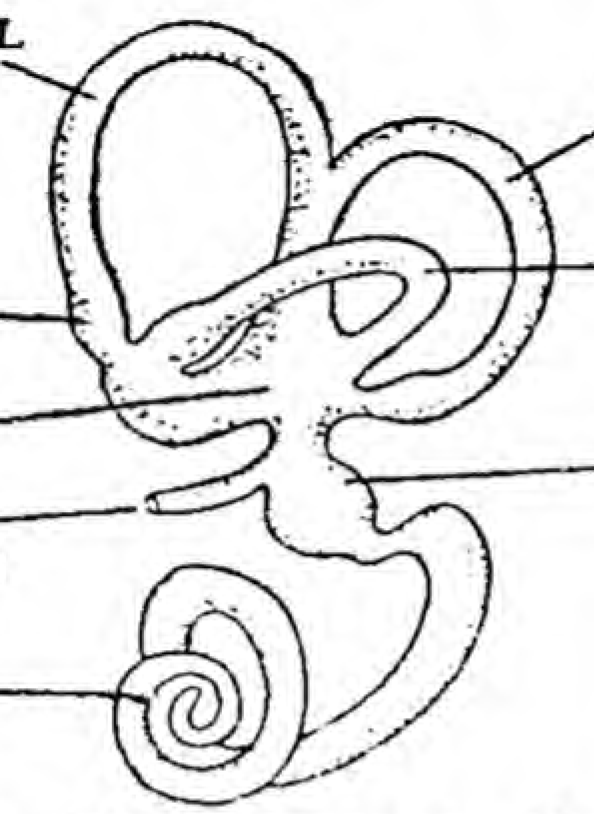


Fig. 22.8. The internal ear of rabbit

similarly-shaped bony labyrinth formed of the periotic bone. The bony and membranous labyrinths are joined together at certain places only. Elsewhere there is a narrow space between the two and this space is filled with a fluid called the **perilymph.** This fluid is in reality the cerebrospinal fluid, the space containing it being in communication with the subarachnoid space round the brain The membranous labyrinth itself is filled with another fluid, the **endolymph,** whose viscosity is two to three times that of water. The membranous labyrinth has three parts : **vestibule, semicircular ducts** and **cochlear duct.**

(*a*) **Vestibule.** The vestibule forms the central part of the membranous labyrinth and is further differentiated into two chambers : the upper larger **utriculus,** which communicates with the semicircular ducts and the lower smaller **sacculus,** which communicates with the cochlea. The two are joined by a constricted area, the **sacculo-utricular duct.** A dorsomedial tube, the **endolymphatic duct,** arises from the sacculus and ends blindly at a short distance. The vestibule has two sensory spots, the **maculae,** for the sense of equilibrium. One of these lies in the wall of the utriculus and is termed the **macula utriculi** ; the other is in the wall of the sacculus and is named **macula sacculi.** Each macula (Fig. 22.9) consists of a group of receptor cells and supporting cells. The receptor cells bear short hair-like processes at the free ends and receive fibres from the vestibular branch of the auditory nerve. The sensory processes of the receptor cells are partly-embedded in a gelatinous mass, the **cupule.** Tiny calcareous particles called **otoconia,** are deposited in the outer part of the cupule.

(*b*) **Semicircular Ducts.** There are three semicircular ducts placed in three mutually perpendicular planes. They are called the **anterior vertical duct**, the **posterior vertical duct** and the **horizontal duct** according

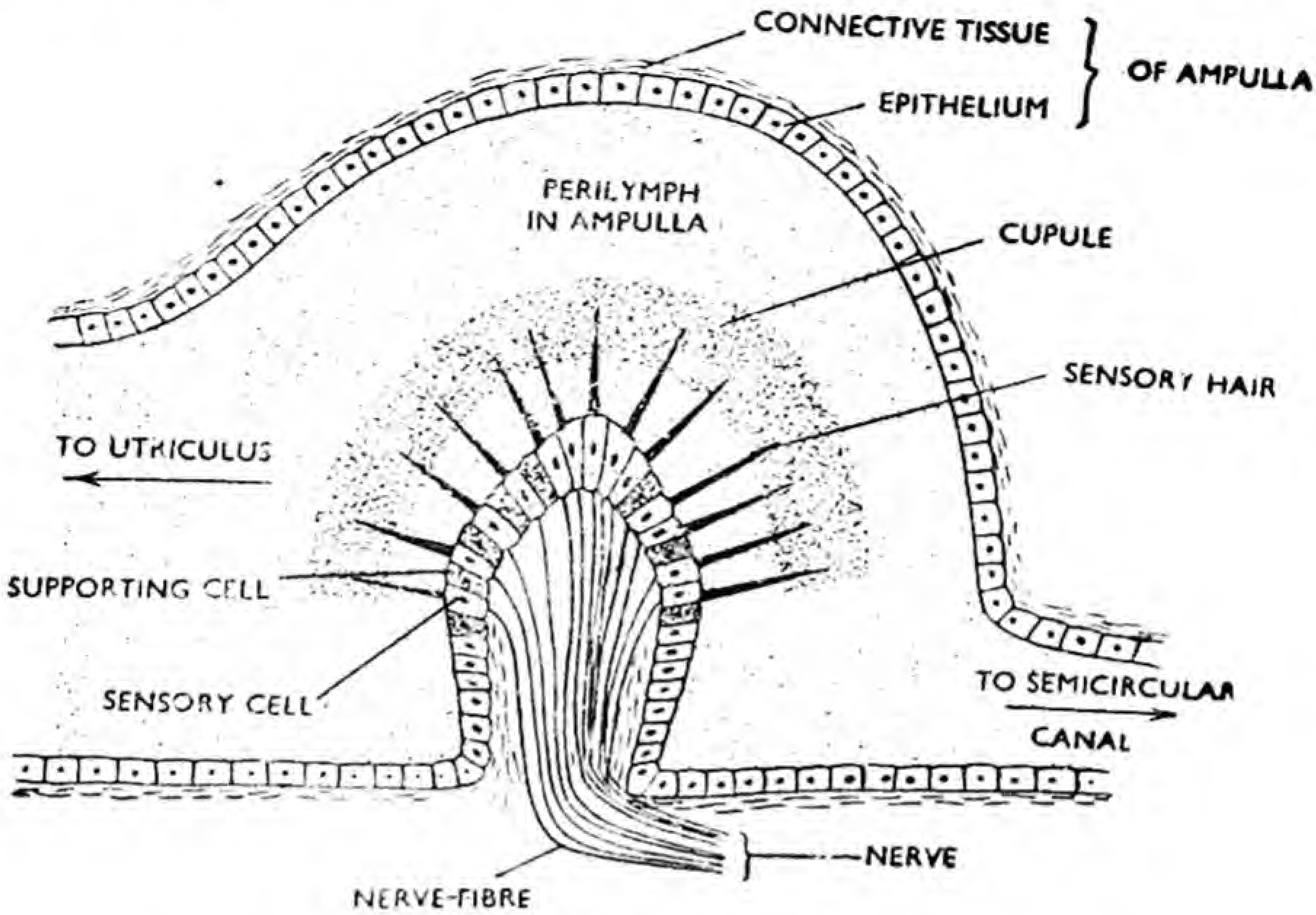


Fig. 22.9. V.S. Crista
(Macula has a similar structure except that the sensory hair of the receptor cells are shorter)

to their position. All open into the utriculus at either end. The anterior and the posterior vertical ducts join together at their adjacent ends to form a common duct, the **crus commune**, which then opens into the utriculus. One (lower) end of each semicircular duct is enlarged to form an **ampulla.** The ampulla of the horizontal duct is situated anteriorly, close to that of the anterior duct. Each ampulla has a sensory patch for the sense of equilibrium. This is called the **crista.** The crista resembles the macula in structure except that the sensory hair of its receptor cells are much longer.

(*c*) **Cochlear Duct.** The cochlear duct is spirally coiled like the shell of a snail and is sometimes also called the **snail's shell.** The part of the bony labyrinth surrounding the cochlear duct is called the **cochlear canal.** The cochlear duct and the cochlear canal together form the **cochlea.** The wall of the cochlear duct is fused with cochlear canal on the sides but is free above and below. With the result, the cochlea shows three chambers, called **scalae,** in transverse section: upper, middle and lower (Fig. 22.10). The middle chamber is called the **scala media.** It is actually the cochlear duct and is an extension from the sacculus. Therefore, it is filled with endolymph. The floor and the roof of the scala media are respectively called the **basilar membrane** and the **Reissner's membrane.** The upper and lower chambers of the cochlea are termed **the scala vestibuli** and the **scala tympani** respectively. They are full of perilymph and both communicate

with each other at the tip of the cochlea. Towards their outer end, the scala vestibuli and scala tympani have a communication with the oval and round window respectively. The basilar membrane bears

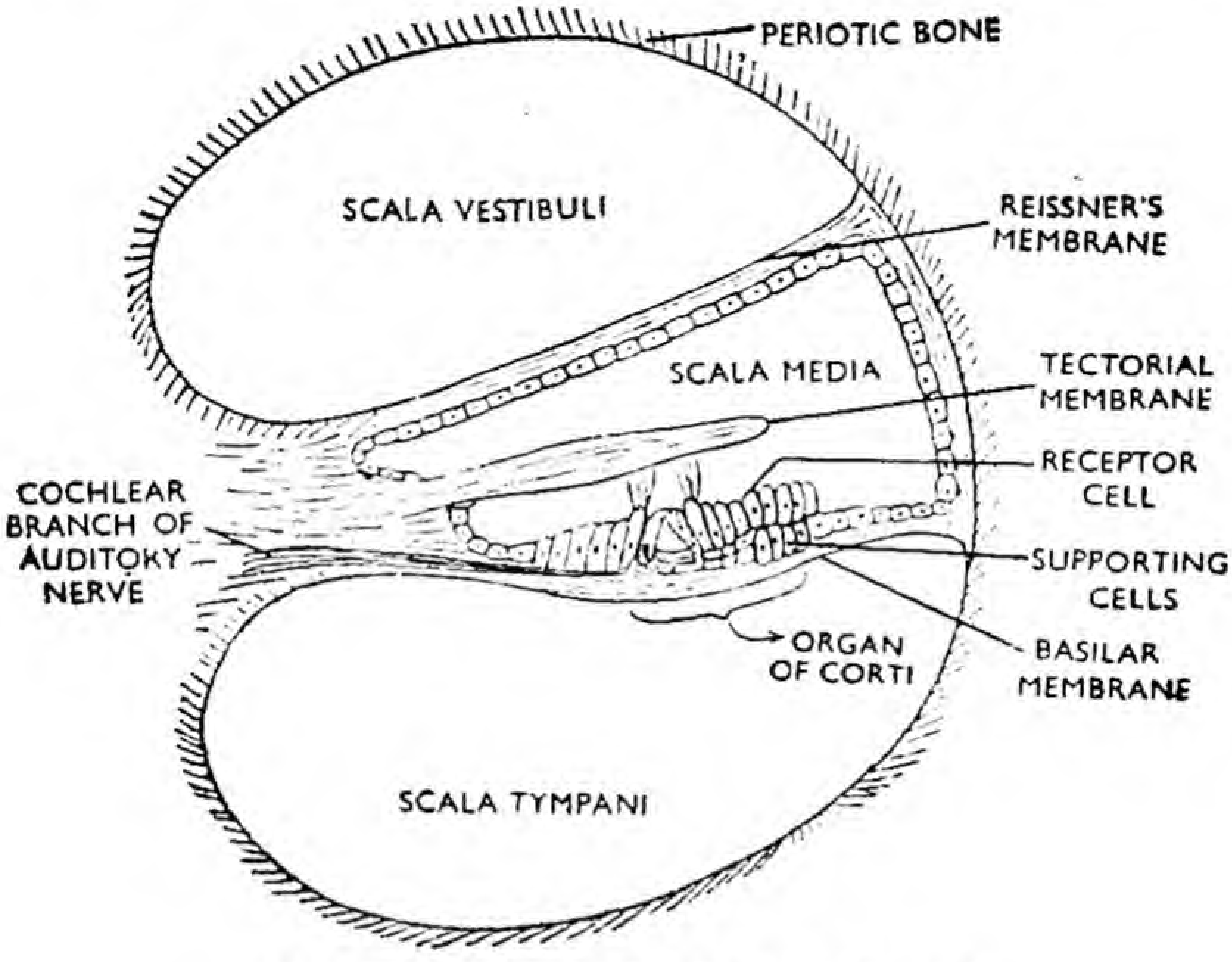


Fig. 22.10. T.S. Cochlea of rabbit

on it the real receptor organ of hearing, the **organ of Corti.** The latter consists of five longitudinal rows of **receptor cells** with tall supporting cells. Each receptor cell bears a tuft of stiff hair-like processes at its free end and receives a fibre from the cochlear branch of the auditory nerve at its other end. A smooth gelatinous ribbon-like membrane, called the **tectorial membrane**, lies over the organ of Corti in such a way that the sensory hair of receptor cells lightly contact it.

The auditory nerve innervates the ear by two branches : the **vestibular branch** going to the semicircular ducts, utriculus and sacculus, and the **cochlear** branch reaching the cochlea.

Function. The ear performs two unrelated functions : hearing and equilibrium.

1. **Hearing.** The sound waves are collected by the pinna, concentrated by the concha, and directed inwards through the external auditory meatus. The waves impinge upon the tympanic membrane which is set into vibrations. From here, the vibrations are transmitted across the middle ear through the ear-ossicles to the membrane over the fenestra ovalis. Sound vibrations are amplified about ten times by the leverage extered by the ear ossicles on the membrane of the oval window. From this membrane, the vibrations pass through the perilymph of the scala vestibuli to the Reissner's membrane. The Reissner's membrane then transmits the vibrations through the endolymph of the scala media to the basilar

membrane. The vibrations of the basilar membrane agitate the receptor cells of the organ of Corti. These cells transform the vibrations into nerve impulses which are conveyed by the cochlear branch of the auditory nerve to the thalamus and thence to the cerebral hemispheres, where the sensation of hearing arises. Vibrations from the perilymph of the scala vestibuli also travel to the tip of the cochlea and, passing through the perliymph of the scala tympani, reach the membrane covering the fenestra rotunda. The fenestra rotunda serves to relieve pressure by the vibrations of its membrane which bulges outward when the membrane of the oval window is forced inwards and vice versa.

2. **Equilibrium**. Cristae and maculae help in the maintenance of equilibrium. Any change in the position of the head sets up movements in the endolymph. These movements disturb the cupule and cause distortion of the sensory hair of the receptor cells. The latter set up nerve impulses which are relayed to the brain by the vestibular branch of the auditory nerve.

TEST QUESTIONS

1. Describe the structure and working of the mammalian eye.

2 Give a detailed account of the ear of rabbit.

3. Give the names and position of the five sense organs. Describe those concerned with smell, taste and touch.

4. Make a list of the essential and accessory parts of the organs of sight and hearing. Explain why these parts are so named.

5. What are the names and functions of the fluids found in the eye and ear of a vertebrate ? Discuss the influence of cutting off the optic and auditory nerves on the animal.

6. Write note on :

Organ of Corti, Retina, Accommodation Power, Pinna, Iris.

CHAPTER 23

Oryctolagus cuniculus

(The Rabbit)

URINOGENITAL SYSTEM

The urinogential system consists of two distinct systems, namely, the **urinary** or **excretory system** and **genital** or **reproductive system**. These systems perform different functions and arise independently during development. But they are described together because they become intimately connected with each other in the adult.

I. EXCRETORY SYSTEM

The excretory system serves to eliminate waste or unwanted materials from the body. These materials include nitrogenous compounds like urea, uric acid, ammonia ; excess of water; various pigments and inorganic salts. All these are eliminated as an aqueous solution known as **urine**. Removal of excess water and salts helps keeping the volume and composition of the blood constant.

Morphology

The excretory system is similar in both the sexes. It comprises a pair of kidneys, a pair of ureters and a urinary bladder.

Kidneys. These are the excretory organs. They are dark-red bean-shaped bodies and are situated in the anterior part of the abdomen, one on either side of the median line, with their con cave sides facing inwards. They are attached to the dorsal body-wall and are covered by peritoneum on ventral side only. Their position is asymmetrical, as the left kidney lies a little behind the right. Probably, the stomach, which lies on the left side, pushes the kidney of this side backwards. Each kidney is composed of innumerable fine tubules, the **uriniferous** or **renal tubules** or **nephrons**. These are interwoven with a network of capillaries, are held together by connective tissue, and are enveloped by

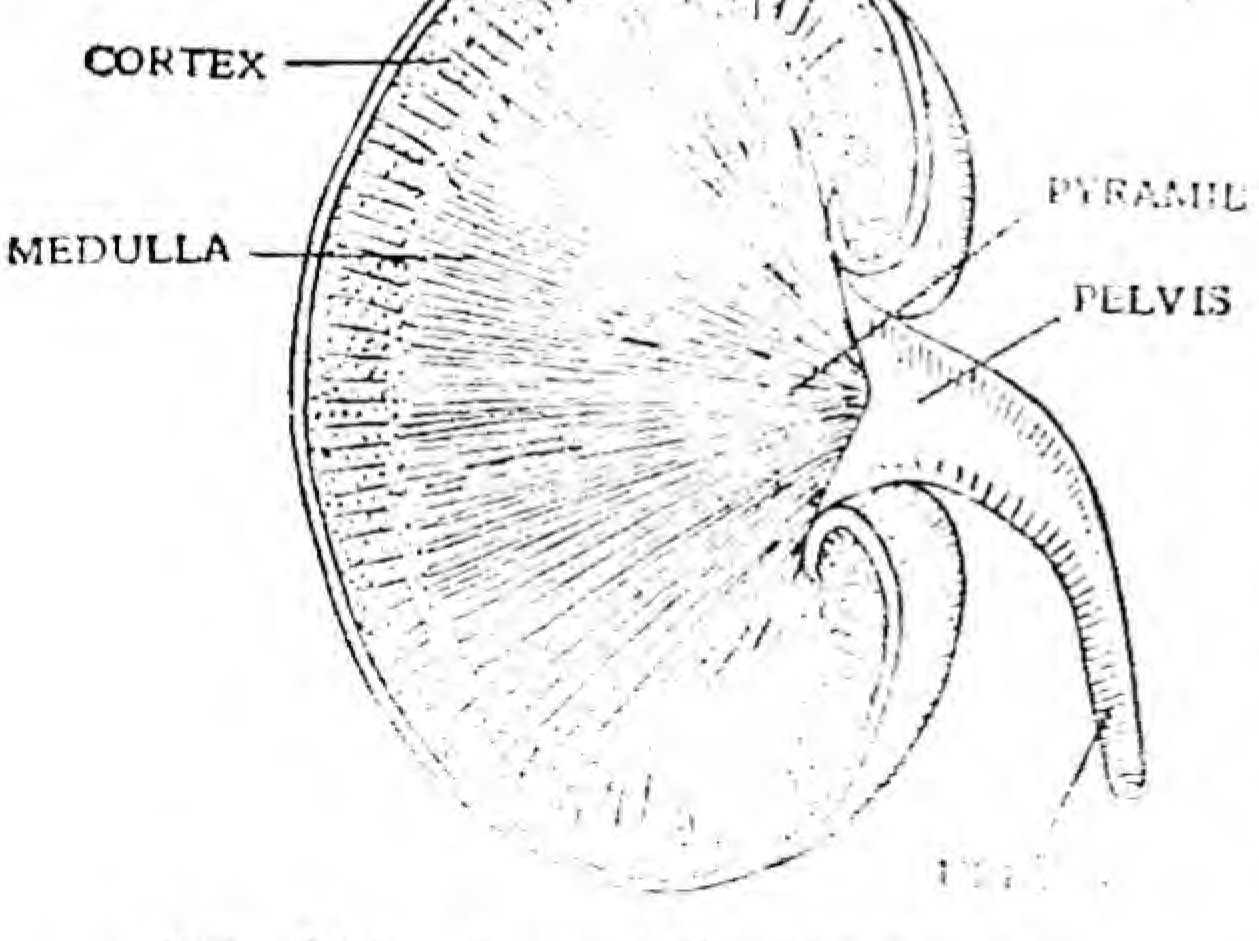


Fig. 23.1. Longitudinal section of the kidney

a **capsule** of fibrous tissue (Fig 23.1). The uriniferous tubules are greatly coiled in the peripheral region of the kidney and run almost straight in the central region. These two regions, therefore, present dotted and striated appearance respectively in section of the kindey and called the **cortex** and **medulla**. One end of each uriniferous tubule (Fig. 23.2) is closed while the other open into a larger tube called the **collecting tube** The closed end is enlarged and depressed to form a double-walled pouch, the **Bowman's capsule**. The latter contains a tightly-fitting bunch of blood-capillaries the **glomerulus**. The Bowman's capsule, and the glomerulus together form the **malpighian body**. Beyond the Bowman's capsule, the uriniferous tubule shows three regions, namely, the **proximal convoluted part** lying in the cortex, the **loop of Henle** situated in the medulla and the **distal convoluted part** which reenters the cortex. The wall of the uriniferous tubule is composed of a single layer of cells which are flattened in the Bowman's capsule and cubical elsewhere. At intervals the cubical cells are ciliated. The collecting tubes pass through the medulla towards the concavity or **hilus** of the kidney where they converge to form a conical process, the **pyramid** which projects into a tunnel-shaped cavity, the **pelvis**.

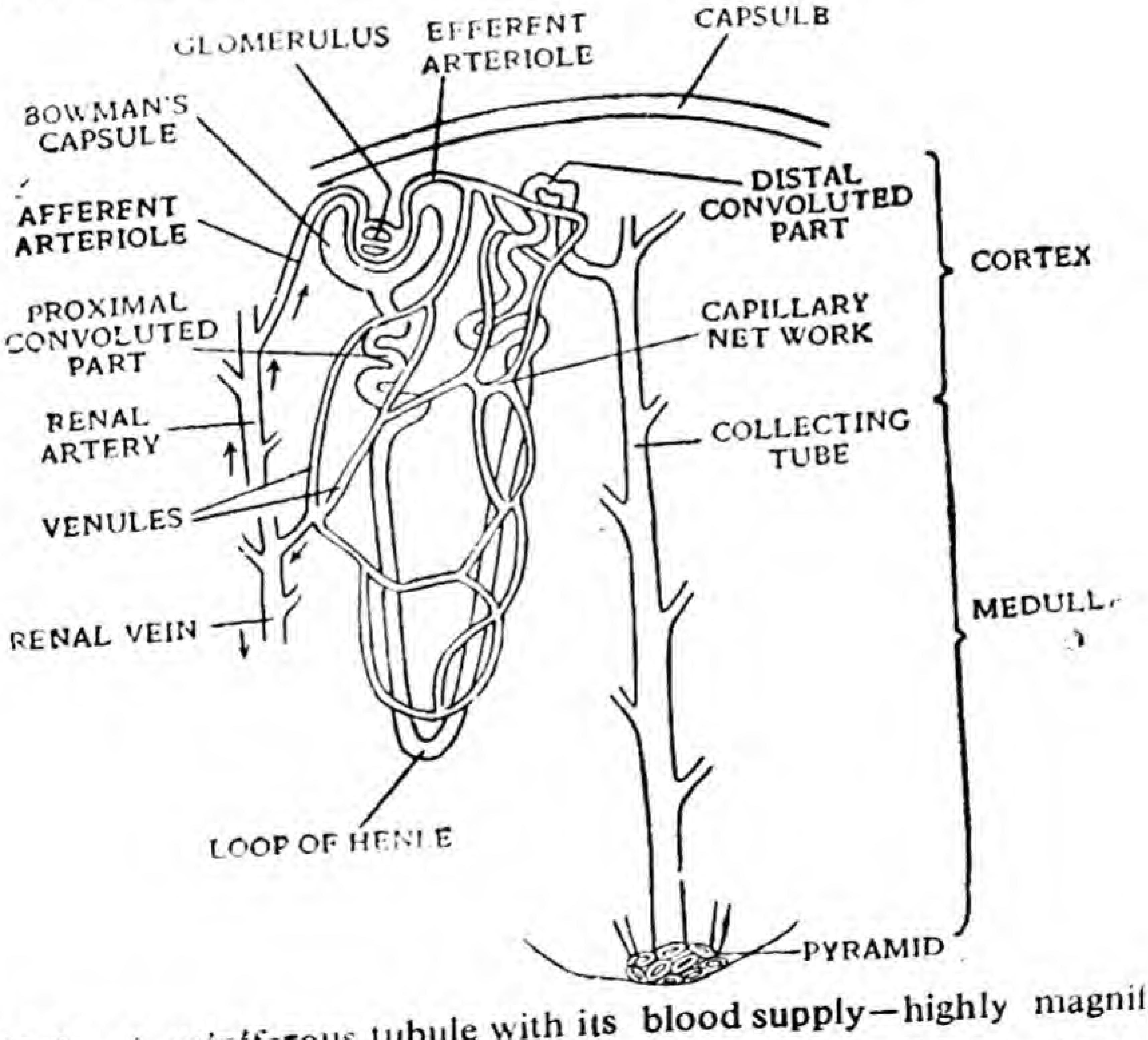


Fig. 23.2. A uriniferous tubule with its blood supply—highly magnified

The **renal artery** after entering the **kidney** divides into a large number of branches, the **afferent arterioles**. Each afferent arteriole enters a **Bowman's capsule** and breaks up into a bunch of capillaries or glomerulus referred to above. The blood from these capillaries is collected by a relatively narrow vessel, the **efferent arteriole**. The efferent arteriole leaves the capsule and breaks up into a network

of capillaries surrounding the urinary tubule. These capillaries then unite to form the venules which, in turn, unite to form the renal vein. The latter leaves the kidney.

Ureters. The pelvis of each kidney is continued into a slender whitish tube, the **ureter**, which leaves the kidney at the hilus. The ureters run backwards along the muscles of the back and open posteriorly into the urinary bladder.

Urinary Bladder. It is a median, pear-shaped, muscular sac, with thin transparent wall. It receives ureters into its dorsal wall. It is situated in the hind part of the abdomen, ventral to the rectum. Its size varies according to the amount of urine in it. The urine is yellow in colour and is visible through the wall of the bladder. The hinder narrow part of the bladder is provided with a sphincter muscle which generally remains in a state of contraction to keep the bladder closed. Beyond the sphincter, the bladder leads into a passage called the **urinogenital canal** which runs backwards through the pelvis and opens to the exterior by **urinogenital aperture.**

The urinogenital canal is acommon passage in the excretory and genital products. It is called **urethra** in the male and **vestibule** in the female. The urinogenital aperture is situated a little in front of the anus. In the male it lies at the tip of a short cylindrical organ, the **penis.** In the female, it is slit-like and is termed the **vulva**.

Physiology

Three distinct processes occur in urine formation. These are called **filtration**, **reabsorption** and **tubular secretion**.

1. **Filtration**. Blood flows through the glomerular capillaries under considerable pressure because the efferent arteriole, which leads from them, is narrower than the afferent arteriole, which leads into them. With this pressure, the water and dissolved substances of the blood are filtered out into the Bowman's capsule through the walls of the glomerular capillaries and the capsule. This filtration occurs by simple diffusion. The filtrate contains in addition to water, urea, sodium and potassium salts, glucose, phosphate, creatinine, amino acids and a few peptides. The blood is left with only corpuscles and complex proteins and fats.

2. **Reabsorption**. From the Bowman's capsule the filtrate passes in to the tubule and flows through it towards the collecting tube by the action of cilia. As it does so much of its contents are reabsorbed into the blood. This reabsorption takes place in two ways : **back diffusion** and **active cellular transport**. Whole of urea that is reabsorbed into the blood, does so by back diffusion. The salts, glucose and amino acids are reabsorbed by active cellular transport. Of the reabsorbed water, major portion enters blood by back diffusion and a small portion by active transport. Diffusion is a physical process so that the cells of the uriniferous tubule have to make no effort to move the materials across them into the blood. Active transport on the other hand, is a vital process and the cells of the tubule have to perform work at the cost of energy in order to push the materials into the blood.

3. Tubular Secretion. As some materials leave the filtrate by their reabsorption into the blood, a few are added to it by secretion of tubule cells. These additions include creatinine, potassium hydrogen ions and ammonia. The filtrate, thus, modified by reabsorption and tubular secretion, is called urine.

The urine produced in the kidneys is carried by the ureters to the urinary bladder by the rhythmical contractions of their walls. The termin· al parts of the ureters act as sphincters to prevent reflux. The bladder serves to store the urine and to discharge it at convenient intervals. During the discharge of the urine the sphincter muscle of the bladder relaxes and the muscles of its wall gradually contract. This slowly drives the urine into the urinogenital canal which takes it to the exterior through the urinogenital aperture. The process of passing out urine is termed **micturition**.

Control of Excretion

Kidneys are under the sole control of hormones like **thyroxin** from the thyroid gland, **cortexone** and **aldosterone** from the adrenal cortex, and **vasopressin** from the posterior lobe of the pituitary body. Deficien- cy of the first three hormones results in the decrease of urine output while that of the last hormone brings about excessive urination.

II. REPRODUCTIVE SYSTEM

The systems discussed so far are concerned with the life of an indivi-

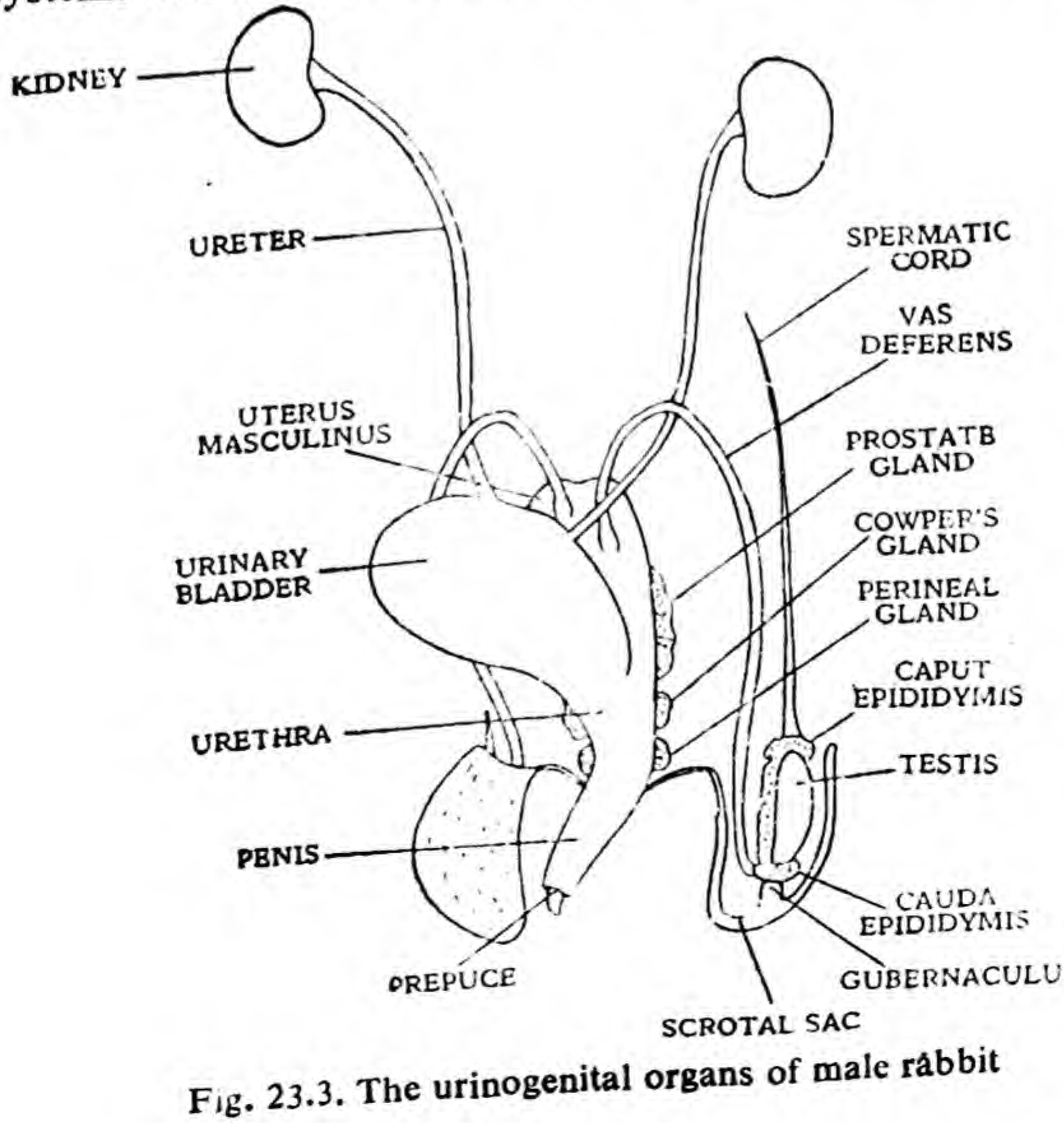


Fig. 23.3. The urinogenital organs of male rabbit

dual animal. The reproductive or genital system, on the other hand, is meant for the production of young ones. This system consists of different organs in the male and the female rabbits.

1. Male Genital System

Morphology. The male genital organs are a pair of **testes**. They are pink oval bodies, about 25 millimeters long. They develop near the kidneys but latter shift backwards and descend into two pouches of the ventral wall of the abdomen, the **scrotal sacs.** This occurs because the higher temperature of the body-cavity is fatal to the sperms Each scrotal sac retains its connection with the abdominal cavity through a narrow passage, the **inguinal canal**. A mass of long, narrow, closely-convoluted tube lies along the inner side of the testis. This is called **epididymis**. It extends in front and behind the testis as the **caput epididymis** and the **cauda epididymis** respectively. The cauda epididymis is joined to the bottom of the scrotal sac by a short, thick, elastic cord known as the **gubernaculum**. A spermatic cord consisting of spermatic artery, vein and nerve along with some connective tissue, joins the caput epididymis with the abdominal wall through the inguinal canal. The testis communicates with its epididymis by fine ductules the **vasa efferentia** which are lined by cilia. From the cauda epididymis, emerges a straight tube called **vas deferens**. It leaves the scrotal sac and enters the abdominal cavity through the inguinal canal. Here it curves round the ureter of its side and proceeds backwards to open into a median sac the **uterus masculinus**. The latter lies dorsal to the urinary bladder. The bladder and the uterus masculinus unite posteriorly to form a common passage, the **urinogential canal** or **urethra**. The urethra passes backwards as a narrow channel through a cylindrical erectile organ, the **penis**. The latter hangs from the ventral wall of the abdomen in front of the anus. Its posterior wall is formed of a spongy tissue, the **corpus-spongiosum**, and the anterior wall is strengthened by a pair of hard structures, the **corpora cavernosa** (Fig. 23.4). The tip of the penis is called **glans**. It is covered by a loose retractable fold of skin, the **prepuce** or fore skin. The penis bears at its lower tip the **urinogential aperture**.

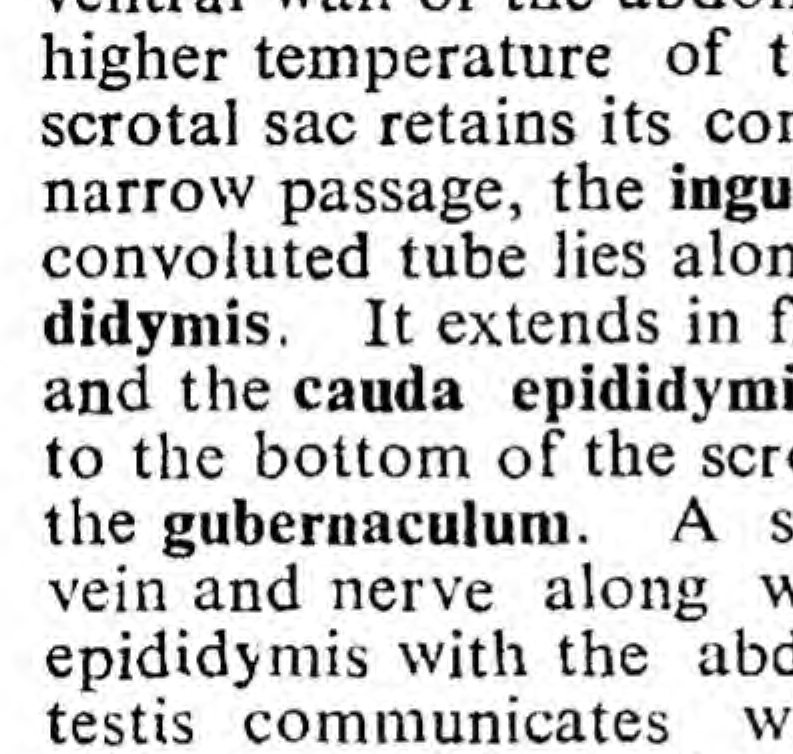


Fig. 23.4. Transverse section through the rabbit's penis (After Vines and Rees)

A few glands are associated with the male genital system. These include the **prostate**, **Cowper's** and **perineal glands**.

The **prostate gland** lies on the dorsal and lateral side of the uterus masculinus. It consists of 4 or 5 lobes which open into urethra by small ducts. It secretes a whitish fluid which nourishes and activates the spermatozoa that have been lying passively in the epididymes during their storage period.

The Cowper's glands are a part of small ovoid bodies placed along the sides of the urethra posterior to the prostate gland. They open by short ducts into the urethra. Their secretion is thought to neutralize the acidity of the urethra and vagina so that the spermatozoa are protected from the action of the acids.

The perineal glands are a pair of dark elongated structures lying next to the Cowper's glands. They open to the exterior in the perineal pouches. Their secretion imparts characteristic odour to the animal.

A pair of **rectal glands** are found on the sides of the rectum in both the sexes. Their function is uncertain.

Physiology. The testes produce **spermatoza** or **male gametes** by an elaborate process of **spermatogenesis**. The spermatozoa are passed on into the epididymes through the vasa efferentia by the action of their cilia. The epididymes serve to store spermatoza for which they are very long and convoluted. The vasa deferentia carry the spermatozoa from the epididymes to the uterus masculinus. The movement of the spermatozoa through the epididymes and vasa deferentia is brought about by the peristaltic contractions of the muscular walls. From the uterus masculinus, the spermatozoa are passed into the vagina of the female during the act of **copulation,** *i.e.* sexual pairing. While passing through the urethra the spermatozoa are fixed with the secretions of the prostate and Cowper's glands to form the **spermatic fluid**. These secretions provide a fluid medium for the transmission of spermatozoa into the body of the female. Besides this, the secretion of the prostate gland nourishes and activates, the spermatozoa and that of the cowper's glands probably neutralizes the acidity of the urethra of the male and vagina of the female to protect the sperms from the acids of the urine.

For copulation, the penis of the male erects and gets stiffened due to sudden rush of blood into its spongy tissue. Now the male mounts the back of the female with his fore-limbs and inserts its erected penis into the genital tract of the female through the **vulva**. During insertion of the penis, its prepuce is pushed back to expose the glans. Friction of this sensitive region with the sides of the genital tract provides the stimulus for the ejaculation of the seminal **fluid** or semen. After this the male retires.

2. Female Genital System

Morphology (Fig. 23.5). The female genital organs are a pair of **ovaries**. They are small, whitish organs in the abdomen behind the kidneys. They are attached to the dorsal body-wall by a fold of peritoneum, the **mesovarium**. The surface of each ovary is marked with several small rounded projections, the **ovarian** or **Graafian follicles,** each containing an **ovum**. When ripe, the Graafian follicles burst to shed the ova.

There are two **oviducts**. Each oviduct shows three regions. Its anterior end is transformed into a wide fimbriated funnel, the **fallopian funnel,** which lies near the outer border of the ovary. The funnel has an

opening, called the ostium, to receive the ova as they are shed by the ovary. The funnel is followed by a narrow, thin-walled, convoluted

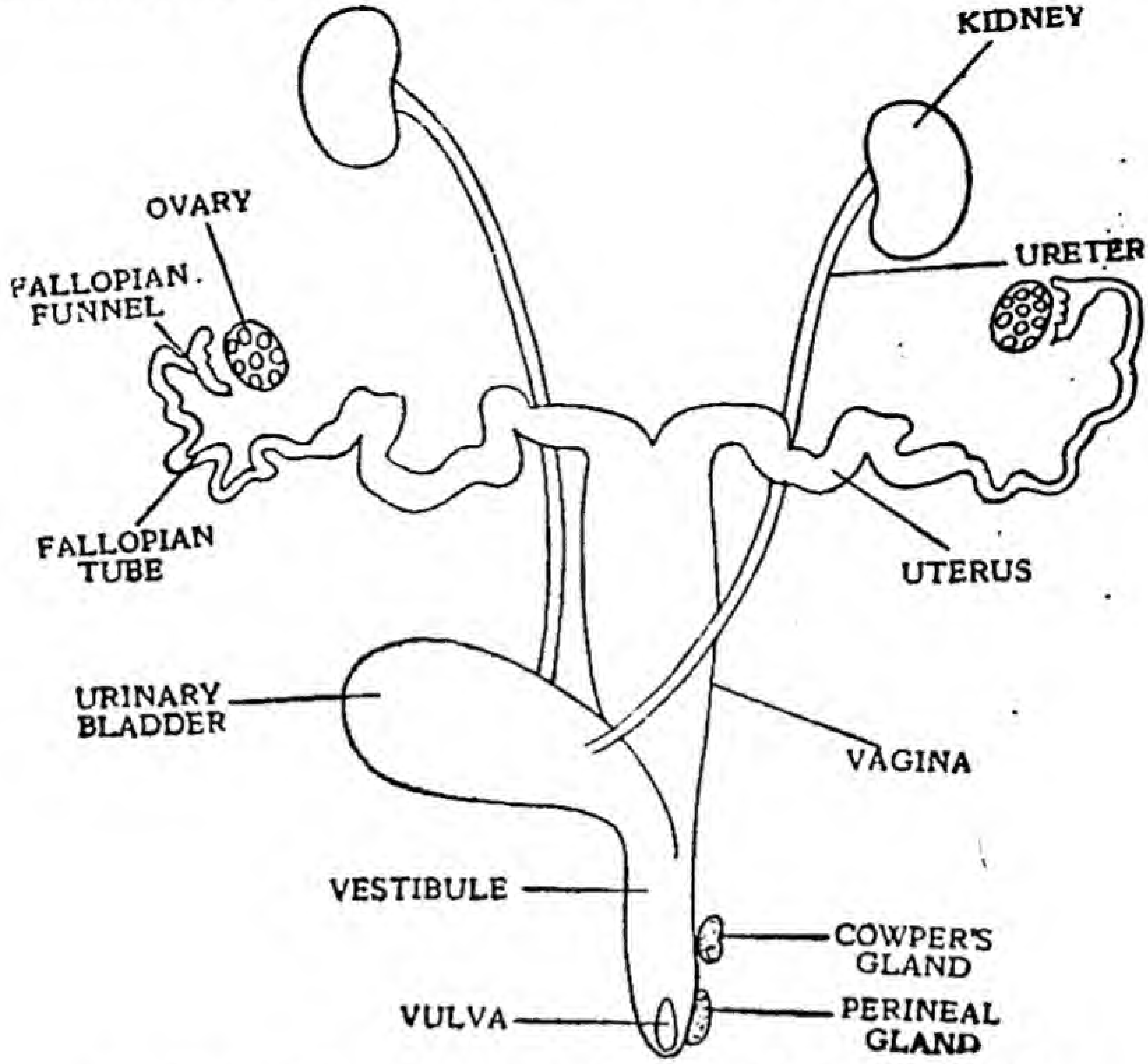


Fig. 23.5. The urinogential organs of female rabbit

part of the oviduct. It is called the **fallopian tube** and is lined by ciliated epithelium. The fallopian tube leads into a broad, thick-walled, relatively less convoluted part, the **uterus.** The uterus is highly vascular and distensible. The follopian tube and the uterus are suspended from the dorsal body-wall by folds of peritoneum called **mesosalpinx** and **mesometrium** respectively. The two uteri run inwards and, crossing the ureters, meet in the median line to form a median sac, the **vagina**. The latter runs backwards dorsal to the urinary bladder with which it unites to form a short common passage, the **urinogenital canal** or **vestibule.** The vestibule extends backwards ventral to the rectum and opens to the exterior by a slit like aperture, called the female **urinogenital aperture** or **vulva**, situated in front of the anus.

A few glands are associated with the female gential system also. These include the Cowper's perineal and rectal glands, all of which are paired. The Cowper's glands lie on the dorsal wall of the vestibule. They are reduced in size and may even be absent. The perineal and rectal glands are like those of the male.

On ventral side of the trunk, there are four or five pairs of **teats or mammae** on which mammary glands embedded in the skin open to the exterior. They become much enlarged after birth of the young ones and start secreting milk for their nourishment.

Physiology. At puberty (sexual maturity), the female goes through periodic **oestrous cycles** or **periods of heat** when she seeks out and mates with a male for breeding purposes. Each oestrous cycle lasts for a few days and is followed by a few days of **anoestrous cycle** in which the female becomes quiescent and does not accept the male. During copulation, the female receives semen from the male in her vagina. The spermatozoa contained in the semen, swim about with their tail and passing forwards through the uteri, reach the fallopian tubes. Soon after copulation, the ovaries shed ova by rupturing the Graafian follicles. Release of ova from the ovary is called **ovulation** and occurs only if there has been copulation. The ova are received by the fallopian funnels and are passed on into the fallopian tube by the action of cilia. In the fallopian tubes one ovum and one spermatozoon fuse together. This fusion is called **fertilization** which is internal in rabbit. The rabbit is now said to be **pregnant**. During pregnancy, recurrence of oestrous cycles remains suspended. The fertilized ova or **zygotes** are slowly carried along the fallopian tubes by ciliary and muscular action, and reach the **uteri** at the end of the third day. By this time each zygote has developed into a small **embryo** or **foetus** by segmentation. After a few days, the foetus gets surrounded by embryonic membranes which enclose fluid that acts as a cushion to protect it from shocks and injury. Later, it develops an intimate connection with the uterine wall by a vascular and spongy structure called the **placenta** In the placenta, the blood capillaries of the foetus and the uterine wall lie very close to each other so that the food and oxygen can diffuse from the uterine blood into the foetal blood and the waste materials, like carbon dioxide and urea, diffuse in the reverse direction. The placenta is, thus, the nourishing respiratory, and excretory apparatus for the foetus. There is no direct mixing up of the foetal and maternal blood. This protects the foetus from the disease germs and other harmful substances which may occur in the maternal blood. On the completion of development of the foetus the uterus undergoes rhythmic contractions which rupture the embryonic membranes, loosen the placental connection between the young and the mother and then gradually expel the young one from the uterus The umbilical stalk is bitten through by the mother and it shrivels up, leaving a scar called the **umbilicus** or **naval** on the young rabbit's abdomen. The process of giving birth to the young ones is known as **Parturition**. After the birth of the young one, the embryonic membranes and the placenta are expelled as the "afterbirth" and the latter is eaten up by the mother. Since the rabbit produces young ones, it is said to be **viviparous**. The duration between fertilization of the ovum and birth of the young ones is called **period of gestation**. It is only one month in rabbit. Long breeding season (January to June or even more) and short gastation period enable the rabbit to bring forth 6-8 litters in a year, each comprising 3-8 young ones.

The newly born rabbits are blind, naked and quite helpless. They are brought up by the mother with great care and affection. Their birth stimulates the mother's mammary glands to produce **milk** on which they are fed during early life. An account of the parental care in rabbit is given in chapter 13.

Control of Reproduction

The reproductive organs, both male and female, are controlled by the nervous and endocrine systems. The nervous system exercises its control through the brain and the autonomic nervous system. The brain controls the reproductive behaviour of the animal while the autonomic nervous system regulates the movements of the reproductive organs. The endocrine system controls the growth and working of the reproductive organs by sending out hormones. Until puberty, the reproductive organs remain under-developed and non-functional. With the approach of puberty, the anterior lobe of the pituitary body secretes two hormones. One of these is called **follicle stimulating hormone** or *FSH* in both the sexes while the other is named **interstitial cells stimulating hormone** or **ICSH** in the male and **luteinizing hormone** or **LH** in the female.

Male. The follicle-stimulating hormone stimulates the testicular tubules which enlarge and start sperm-formation by spermatogenesis. The interstitial cells stimulating hormone, as its name indicates, stimulates the interstitial cells of the testes to produce the male hormone called **testosterone**, which induces the various organs and glands of the male genital system to grow to full size and become functional.

Female. The follicle stimulating hormone brings about the growth of the ovaries and maturation of their follicles. As the ovarian follicles mature, the cells lining them start secreting the female hormones called **oestrogens**. The latter induce the various parts of the female gential tract to grow to full size and become functional. They also result in the development of secondary sexual characters. The luteinizing hormone in cooperation with the follicle-stimulating hormone, brings about ovulation. After the release of the ovum, the empty follicle develops in it a yellowish mass, the **corpus luteum**, which produces a hormone known as the **progesterone** This hormone suspends ovulation during pregnancy, develops and maintains the placental connection between the foetus and the uterine wall, and influences the growth of the foetus. Later, the corpus luteum produces another hormone, namely, **relaxin** which widens the pelvic girdle during birth.

TEST QUESTIONS

1. Give an account of the reproductive system of male rabbit. Discuss the functions of each part-
2. Describe the female urinogenital system of rabbit
3. Explain the following terms :—
   Fertilization, Gestation period, Parental Care, Placenta, Glomerulus,
4. Give an account of the formation of urine and its elimination from the body
5. Describe the urinary system of rabbit.

Oryctolagus cuniculus

(The Rabbit)

ENDOCRINE SYSTEM

The endocrine system regulates the functioning of various organs of the body sending chemical messengers to them. This system consists of isolated organs called the **endocrine** or **ductless glands**. They receive their name from the fact that they have no ducts to drain away their secretions which, therefore, diffuse directly into the blood that carries them to the parts of the body where needed. The secretions are produced by the glands from the substances supplied to them by the blood. The circulatory system is, thus, vital to the endocrine system as it supplies the raw materials and drains away the finished products. The endocrine glands are usually small in size being very much out of proportion to the vital influence exerted by them on the body.

Types of Endocrine Secretions. Secretions of endocrine glands are known as **autacoids** or more commonly **hormones**. The autacoids affect the body, in two ways. Some of them stimulate activity in some organ of the body, others suppress or inhibit it instead. For the stimulating

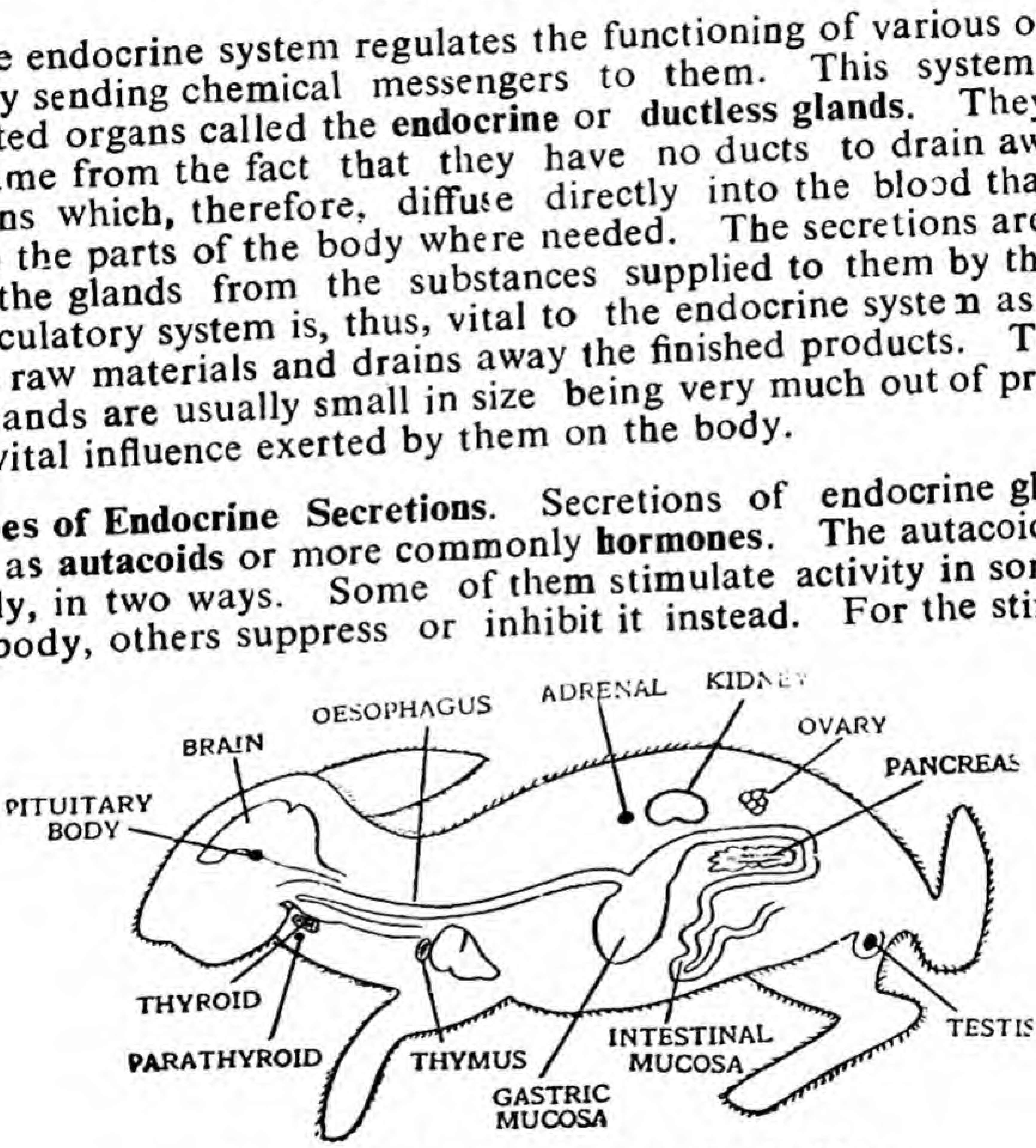


Fig. 24.1. The endocrine glands of rabbit

autacoids, the name hormones in quite appropriate because it means 'exciter.' For the inhibiting autacoids, more proper name is **chalones** which means to "relax" However, the term hormone is often used for all autacoids, both exciters and depressors though it is technically wrong.

Types of Endocrine Glands. The endorcrine glands may be grouped into two categories : those devoted entirely to secretion of hormones and those partly endocrine in function. The first category includes six glands, viz. **thyroid, parathyroids, thymus, adrenals. pituitary and pineal**. The second category comprises the groups of gland cells situated in organs like pancreas, gonads and alimentary canal (Fig.24.1.). Being of dual purpose these are sometimes called **heterocrine glands**

I. The purely endocrine glands will be described first.

1. **Thyroid**. The thyroid is a bilobed structure situated just beneath the larynx. It secretes an iodine-containing hormone called the **throxine.** This hormone regulates the rate of oxidation of food in the body, in order to liberate the required amount of energy for muscular activity. The hypersecretion *i.e.* excess of this hormone, increases the rate of oxidation and leads to quick consumption of food so that nothing remains for storage as fat. This in turn results in quick heartbeating, warm skin, nervousness and in some cases in bulging eyes. The disorder can be cured by a surgical removal of a part of the gland.

Deficiency of thyroid hormone produces opposite symptoms. It reduces the rate of oxidation and leads to fat formation in the body. Activity of heart and nervous system is retarded. The deficiency produces **cretinism** in the infants and **myxoedema** in the adults. A cretin shows stunted growth, awkward body, mental backwardness and retarded sexual development. In myxoedema, there is thickening of the subcutaneous tissue, muscular weakness and reduced basal metabolism. Both the conditions can be treated by giving thyroxine or feeding on thyroid.

Thyroxine also controls the working of kidneys. Its deficiency results in decreased urine output and vice-versa.

A pathological enlargement of thyroid, called goitre, develops from deficiency in iodine needed to manufacture its iodine containing hormone.

2. **Parathyroids**. The parathyroids are four small glands placed on the thyroid, two on each lobe. They secrete a hormone called **parathormone** or **Collips hormone** after its discoverer. It regulates the calcium-phosphorus balance in the blood. The growth of bones, muscle tone and normal nervous activity is dependent on a fixed calcium-phosphorus balance.

3. **Thymus**. The thymus is a large, soft, pinkish mass situated in front of the heart around the roots of the great blood-vessels. It gradually atrophies in the adult. Mainly it is a lymphoid tissue but secretes a hormone. The thymus hormone accelerates the growth and division of cells and, thus, influences the rate of growth during early life. It also hastens attainment of sexual maturity.

4. **Adrenals**. The adrenals, also called **suprarenals**, are a pair of small, flat, ovoid, whitish glands located one in front of each kidney. Each gland consists of two regions : outer **cortex** of mesodermal origin and inner **medulla** derived from nervous tissue. The cortex secretes many

hormones, the more important of which are **cortisone, cortexone, aldosterone and sex hormones**. The cortisone regulates the carbohydrate and protein metabolism. Its deficiency causes **Addison's disease** in which the patient experiences muscular weakness, nervous depression and low blood-pressure : Cortexone influences salt and water metabolism. Aldosterone controls salt and carbohydrate metabolism.

The medulla produces two hormones : **epinephrin (adrenalin)** and **norepinephrin (noradrenalin)**. The latter regulates blood pressure under routine circumstances. The epinephrin is secreted at the time of emergency to prepare the animal for facing special conditions created by muscular exertion and emotional factors like fear, anger, pain etc. All these conditions require greater amount of energy which is provided by increasing heart beat, blood-pressure, respiratory rate, muscle tone, level of sugar in the blood and blood supply of skeletal muscle and brain. Besides serving as a whip for emergencies this hormone also helps in carbohydrate metabolism when required. Because of the action of this hormone, the adrenals are often described as the "glands of emergency."

5. **Pituitary**. The pituitary is attached to the ventral side of the brain (diencephalon) and lies in a depression on the floor of the cranium. It consists of three parts : the anterior, intermediate and posterior lobes. The anterior and intermediate lobes develop as an outgrowth from the roof of the pharynx while posterior lobe originate as a downgrowth from the floor of the brain. The anterior lobe secretes seven distinct hormones. Of these two are called **gonadotropic** or **gonad-controlling hormones**. They influence growth and functioning of the gonads. One of these is called **follicle-stimulating hormone** (FSH) in both the sexes. It regulates the production of gametes—eggs and spermatozoa. The second is known as the **interstitial cells stimulating hormone** (ICSH) in the male and **luteinising hormone** (LH) in the female. The former induces the interstitial cells of the testes to produce male hormone termed **testosterone**. The luteinising hormone of the female causes ovulation and secretion of **progesterone** by the corpus luteum. The third hormone of the anterior lobe is the **somatotropic or growth hormone** (STH). It regulates the protein metabolism and the growth of the skeleton. The deficiency of this hormone produces **dwarfism or infantilism**. The dwarft produced by the deficiency of this hormone differ from those resulting from the deficiency of thyroid hormone in having normal intelligence. They are only "men in miniature". The excess of the growth hormone affects differently in the young and the adult stages During the growth period, the excess results in **gigantism**, *i.e.* the production of giants with abnormal heights. In the adult stage, the excess of the growth hormone produces a condition called **acromegaly**. In acromegaly there is abnormal growth of the face, hands and feet. The remaining hormones of the anterior lobe include the **adrenocorticotropic** or **adrenal-cortex-controlling hormone**(ACTH) which stimulates the secretion of the hormones by the cortex of the adrenal glands **thyrotropic** or **thyroid controlling hormone** (TSH) which) stimulates the production of thyroid hormone, **pancreatotropic** or **pancreas-**

controlling hormone which suppresses the production of insulin by the islets of Langerhans of the pancreas and **lactogenic hormone** which controls the development of milk glands and secretion of progesterone.

The intermediate lobe of the pituitary gland secretes a hormone named **intermedin** which induces the pigment to disperse throughout the melanophores or pigment cells, thereby darkening the colour.

The posterior lobe of the pituitary gland secretes two hormones : **oxytocin** and **vasopressin**. The former induces contractions of the uterus during parturition and also causes release of milk from the mammary glands. Vasopressin controls blood-pressure, causing contraction of all blood vessels except those going to the kidneys. It also controls excretion of water by kidneys. Its deficiency increases urination and causes excessive thirst. The defect is called **diabetes insipidus**.

Due to the number of hormones it produces and the control it exercises over other endocrine glands, the pituitary fully deserves the title "**Master Endocrine Gland**" often given to it

6. **Pineal**. The pineal lies on the roof of the brain. It is, in fact, a remnant of the median eye. Now an endocrine function has been assigned to it. The nature and role of its hormone are not known. Probably it regulates the working of gonads indirectly by influencing the pituitary hormone.

II. The partly endocrine glands are discussed below.

1. **Pancreas** The pancreas is both a digestive as well as an endocrine gland. Besides the lobules, which secrete the pancreatic juice, it also contains groups of special cells of the **islands of Lagerhans**, which secrete hormones. The cells of the islands are of two types : alpha and beta, The beta cells secrete an important hormone called **insulin**. This hormone enables the liver to store glucose as glycogen. It also enables the tissues to use glucose as source of energy. It, thus, controls the carbohydrate metabolism. Insulin deficiency makes the animal unable to use or store sugar. Thus the tissues are deprived of energy-producing food and sugar collects in the blood. From the blood it is excreted by kidneys and is passed in urine. This disorder is called **diabetes mellitus** It can be cured with an injection of insulin. The alpha cells of the **islands** produce a hormone named **glucagon** whose action is reverse of that of insulin. It brings about the release of glucose from the liver, thus, increasing its percentage in the blood.

2. **Gonads**. The gonads, besides producing gametes. also secrete hormones.

(*i*) **Testes**. Testes produce **testosterone** or male sex hormone from small groups of special cells, called **interstitial** or **Leidyg's cells**, situated between the sperm producing tubules The testosterone makes the various organs and glands of the male genital system to grow to full size and become functional. It is also responsible for the formation of secondary sexual characters like hair on the face in man.

TABLE 11

Summary of Hormones

Gland	Position	Hormone	Function
1. Thyroid	Beneath larynx	Thyroxine	Regulates oxidation of food its deficiency produces cretinism in children and myxoedema in adults.
2. Parathyroids	On thyroid	Parathormone	Regulates calcium-phosphorus balance in blood.
3. Thymus	In front of heart		Regulates growth.
4. Adrenals	In front of kidneys	Cortisone	Regulates carbophydrate metabolism. Its deficiency causes Addison's disease.
		Cortexone	Influences salt and water metabolism.
		Aldosteron	Controls sait and carbohydrate metabolism.
		Adrenaline	Controls involuntary muscles and blood pressure under emergency.
		Noradrenalin	Regulates blood pressure under routine circumstances.
5. Pituitary (a) Anterior Lobe	Beneath brain	Somatotropic	Regulates protein metabolism and growth of bones Deficiency causes dwarfism excess produces gigantism and acromegaly.
		Gonadotropic	Controls development and functioning of gonads.
		Lectogenic	Controls development of milk glands.
		Adrenocorticotropic	Stimulates secretion of adrenal cortex.
		Pancreatotropic	Controls secretion of pancreatic hormone.
		Thyrotropic	Stimulates secretion of thyroid hormone.
(b) Intermediate lobe		Intermedin	Controls skin colour
(c) Posterior		Oxytocin	Regulates uterine contractions and release of milk
		Vasopressin	Controls blood pressure and urination.
6. Pineal	Roof of brain	—	Regulating working of gonads
7. Pancreas	In duodenal loop	Insulin	Controls carbohydrate metabolism its deficiency causes diabetes mellitus.
		Glucagon	Release of sugar from liver.
8. Gonads (a) Testes	In scrotal sacs	Testosterone	Develops male organs and secondary sexual characters.
(b) Ovaries	Behind kidneys	Oestrogens	Develop female organs and secondary sexual characters.
		Progesterone	Stops egg production attaches foetus to uterine wall.
		Relaxin	Widening of pelvis at parturition.
9. Alimentary Canal	Body cavity	Gastrin	Stimulates the secretion of Juice.
		Secretin	Stimulates secretion of pancreatic juice.
		Cholecystokinin	Stimulates gall-bladder to release bile.

(*ii*) **Ovaries**. The ovaries produce three hormones, **oestrogens**, **progesterone** and **relaxin**. The oestrogens are secreted by the follicle cells surrounding the egg. They induce the various parts of the female genital tract to grow to their full size and become functional. They are also responsible for the development of secondary sexual characters in the female like mammary glands. The progesterone is secreted by the **corpus luteum** which is a yellowish mass of cells filling the empty follicle after the liberation of the egg. It stops the formation of eggs, attaches the foetus to the uterine walls by placenta and controls the development of foetus in the uterus. Relaxin is also produced by the corpus luteum. It widens the pelvic girdle during birth.

3. **Mucous Membrane of the Alimentary Canal**. It secretes a few hormones which stimulate the production of digestive juices. The epithelium of the pyloric stomach secretes a hormone called **gastrin which** stimulates the gastric glands to produce the gastric juice. The duodenal epithelium secretes two hormones : the **secretin** which activates the pancreas to release pancreatic juice and **cholecystokinin** which stimulates the gall-bladder to release bile.

Importance of Endocrine System. The endocrine system is very important for the proper functioning of the body. Any major disturbance in any endocrine gland will result in serious complications which may make the animal abnormal and even cause death in a short time. Because of their importance in the vital activities of the body, the study of endocrine glands, called **endocrinology** is making very rapid progress.

TEST QUESTIONS

1. What is a gland ? Differentiate between the endocrine and exocrine glands, giving examples of each. Describe at least one gland of each type.

2. Name and describe important endocrine gland of a vertebrate.

3. What are hormones ? Where are the following hormones produced and what role do they perform in the body ?

   Insulin. Oestrogens. Adrenalin,

4. Write notes on the following :—

   Dwarfism, Cretinism, Pancreas, Pituitary body, Diabetes mellitus.

CHAPTER 25

Oryctolagus cuniculus

(The Rabbit)

ADAPTATIONS AND CLASSIFICATION

I. Adaptations

The rabbit shows adaptations mainly for homoiothermy, viviparity lack of active defence, high rate of multiplication, and leaping form of locomotion.

1. **Adaptations for Homoiothermy**. Homoiothermy, *i.e.* maintenance of constant body temperature, depends on factors like sufficent supply of food to the tissues, efficient respiratory and circulatory systems, and means to check heat loss. Rabbit has suitable adaptations for all these factors.

There are many devices in rabbit to supply sufficient food to the tissues. It takes almost any kind of plant material it comes across. Great length of its intestine results in maximum absorption. Bacterial inhabitants of its caecum simplify cellulose from which extra nourishment is derived later by coprophagy.

Efficiency of the respiratory system has been enhanced in rabbit by the separation of food and breathing passages; supply of clean moist and warm air to the lungs and the enormous; surface provided by the millions of alveoli of the lungs for the exchange of gases.

Efficiency of the circulatory system lies in the fact that it sends fully aerated blood to all parts of the body. This facilitates oxidation of food for the release of energy, part of which warms up the body.

The loss of heat from the body is prevented by the hairy coat over the skin and the fat deposited in the subcutaneous tissue. Over heating of the body is checked by the sweat glands whose secretion cools the skin.

2. **Adaptations for Viviparity**. Viviparity, *i.e.* giving birth to living young, involves three prerequisites, namely, internal fertilization, provision for the nourishment, respiration and excretion of the young while in the mother's body, and care of the young for some time after birth. The rabbit has adaptations for all these requirements.

The erectile penis enables the male to shed the spermatozoa well inside the genital tract of the female for internal fertilization.

The placenta provides an ideal means for the nourishment, respiration and excretion of the foetus, It brings the maternal blood very close

to the foetal blood so that food and oxygen may readily diffuse from the maternal to the foetal blood and carbon dioxide and nitrogenous wastes from the foetal to the maternal blood.

Automatic onset of lactation soon after the birth of the young ones, enables the mother to feed them on milk till they take to their normal diet.

3. **Adaptations for Lack of Active Defence.** Lack of active defence has been compensated in rabbit in more than one ways. Fossorial or burrowing life, is one such device. The structures that help in this mode of life include the limbs, nictitating membrane and vibrissae. The fore-limbs are used for scratching the earth and hind-limbs for throwing it back. The nictitating membrane prevents the entry of soil particles into the eyes. The vibrissae determine the width of the burrow at its farthest end where there is sufficiently dark for the eyes to see.

Crepuscular habit also provides protection against enemies. At dusk and dawn, when the rabbit comes out of its burrows for feeding and playing, they are comparatively few enemies.

Gregarious nature, *i.e.* moving about in large groups, makes the rabbit more watchful of its enemies. Any one in the group, on seeing enemy, will thump its hind-limbs on the ground to produce a warning sound, hearing which all run to safety.

Camouflage is yet another device for defence. The dust-brown colour of the wild rabbit wonderfully matches with the background and makes it barely discernible.

Lastly the speed, which may reach 32 to 40 kilometres per hour also confers on rabbit some measure of protection from enemies.

4. **Adaptations for High rate of Multiplication.** The factors that promote the rate of multiplication in rabbit include attainment of sexual maturity at an early age of six months, short gestation period which is just one month, multiple births (3-8 young ones in a litter), and production of several litters (up to six) in a year. The gregarious habit is also helpful in this respect. It enables the female to easily find a mate as and when she is in heat.

5. **Adaptations for Leaping.** Rabbit possesses a few significant adaptations in its limbs and girdles for leaping. The centre of gravity in the normal resting position is far back, being nearly between the hind-limbs. Large area of the feet in contact with the ground and long segments of the hind limbs bent like a spring (*z*) increase the thrust produced by straightening of the hind-limbs. To transmit this thrust the axis of the body, the pelvic girdle lies parallel to the vertebral column and is fused with sacrum. To reduce the shock of landing on the ground after a leap, the short but stout fore-limbs have a bend at the elbows, the hands touch the ground with the digits only and the pectoral girdle is springy.

II. Classifications

The rabbit is assigned to the

Phylum	: Chordata	Because of having notochord, gill-slits and dorsal hollow central nervous system.
Sub-phylum	: Vetebrata (Craniata)	Because of having vertebral column and cranium.
Class	: Mammalia	Because of having hair, pinna, diaphragm and mamary glands.
Sub-class	: Theria	On account of being viviparous.
Infra-class	: Eutheria (Placentalia)	Due to having true placenta and prolonged intra-uterine development.
Order	: Lagomorpha	Because of having a second pair of smaller incisors in the upper jaw.
Family	: Leporidae	Because of having elongated hind-limbs, long pinnae and short recurved tail.
Genus	: *Oryctolagus*	Because of fossorial, crepuscular and gregarious nature and because of having vertical groove on the anterior surface of the front incisors and a distinct interparietal bone in the skull. Moreover, the young ones are naked, weak and blind at birth.
Species	: *O. cuniculus*	The bucks and does are almost alike, fur is dense and wooly and is short with white underside.

TEST QUESTIONS

1. Give an account of the adaptations of rabbit.
2. Give a detailed classification of rabbit.
3. Explain the terms—

Homoiothermy, Viviparity, Fossorial Animal, Crepuscular Animal, Camouflage.

CHAPTER 26

Principles of Classification and Nomenclature

I. Classification

Purpose of Classification. What would you do if you were asked to pick up a particular coin from a heap of several hundered coins belonging to many countries ? You would probably first sort out the coins countrywise. By doing this you would have many smaller heaps. Then, in each heap, you would find many sets of coins issued from time to time. The heap of each country would, thus, be sub-divided into many small piles. In each pile there would be coins of different denominations These you would arrange in order. After this arrangement, it would become very easy for you to find out the coin of the given description.

The same is required to be done with the animals whose number is enormous. It is rather difficult to give the exact number of different kinds of living animals. About a million of them have already been described, many are discovered as new forms every year, and a large number lived in the past. They vary tremendously in their form, structure and mode of life. To find out an animal of known characters from the vast assemblage of animals is simply impossible. They must be devided into groups and sub-groups. The grouping of animals according to a definite plan makes the study of animals convenient. It is not possible for a man to acquaint himself separately with all the known animals but the study of a few representatives from each group will enable him to have a broad idea of the animal life as a whole.

History and Systems of Classification. The history of classification is almost as old as man himself. The early man grouped the animals on the basis of their utility to him. He distinguished between the harmful and useful animals, edible and inedible ones. Even now we recognize the animals as the food animals, fur animals, pets, beasts of burden, wild game, etc. This system of grouping the animals from the point of view of their value to man, irrespective of their similarities, is called the **practical classification.**

Later, the Greek naturalists classified the animals according to their similarities in habits, etc. The animals were grouped as aquatic or water-dwellers, terrestrial or land dwellers and aerial or air-dwellers ; carnivores or flesh-eaters and herbivores or plant eaters; oviparous or egg-layers and viviparous or young-producers; and so on. This system of classification, based on superficial resemblances, is called the **artificial**

classification. Aristotle (384—322 B.C.), the "father of zoology", was the first to adopt this system of classification. It remained in vogue for about two thousand years. The early Greek naturalists had little knowledge of the animal structure which, consequently, could not be used by them in classification.

An Englishman, John Ray (1627—1705), was the first systematist to form the structure the basis of classification. He formed a few groups but his scheme of dividing each larger group always into two sub-groups did not prove practicable. This system of grouping the animal on the basis of their structural resemblances is called the **natural classification**. It is the most rational system of classification and has been adopted by all the zoologists. It not only makes the study of animals convenient but also indicates the true evolutionary relationship between them. It is also helpful in the identification of animals.

The system of natural classification was placed on firm footing by the Swedish biologist Carolus Linnaeus (1707—1778). He is often referred to as the "father of classification" because his scheme, with a few additions, is still used. He divided the **world** of living objects into two **kingdoms**—plant and animal. Each kingdom was split up into large groups called **classes**. A class was sub-divided into smaller groups termed **orders**. An order was separated into still smaller groups known as **genera**. Finally, in each genus were placed one or more **species**. Linnaeus published his scheme of classification in the famous book "Systema Naturae". His classification served a good purpose for quite a long time. It, however, became inadequate with the discovery of a large number of new animals since his times. This paved the way for the modern classification.

The modern classification is simply the expanded form of the Linnaean classification. Two more divisions have been added to those proposed by Linnaeus. These are **phyla** and **families**, the former above the classes and the latter between the orders and genera. The main divisions in the modern classification, thus, the phyla, classes, orders, families, genera and species. Besides, these, the prefixes super- and sub- are sometimes added to the main divisions to form new groups like **sub-phylum, sub-class, super-order, sub-order**, etc.

The species is usually the smallest unit **in** classification. It may be defined as a group of animals which resemble one another in all essential respects, differ visibly from all other animals, and inter-breed freely to produce the fertile young. The individuals of a species are similar because they all are the discendants of the same ancestor. They differ from one another only as much as the offspring of the same parents do. Sometimes, the individuals of a species are divisible into still smaller groups on the basis of minor but distinct variations. Such sub-groups are called **varieties**.

II. Nomenclature.

Need for Scientific Names. For the classification of animals, it is essential that all of them should be provided with names. From the earliest times, man has given common names to the animals living

around him. These names, however, have little value in classification as they though easier to pronounce and remember, have a number of drawbacks. In the first place, the common names are inadequate. Only those animals which are closely associated with human life have been given these names. Quite a large number of animals living far away from human habitations have no common names. Then, the same animal is known by different names in different countries. Even within one country, an animal may have many local names. The common names of one country or locality are not understood by the inhabitants of another country or locality because of the different languages used by the people. Again, in some cases, a single common name refers to more than one animals. Moreover, no system has been followed in selecting the common names. They may indicate a superficial character (blackbird), a habit (flying fish), a habitat (tree frog) or a use (pearl-oyster). Lastly, the common names are sometimes misleading. Look at the common names "dog-fish", "silver-fish", "cuttle-fish", "jelly-fish", "star-fish", "cray-fish". These names seem to indicate the types of fish but it is not true. A fish is a vertebrate animal with backbone, gills and fins. Only the "dog-fish" has these characters and is a true fish". Others are invertebrates. The "silver-fish" is an insect, "cuttle-fish" a molluse, "jelly-fish" a coelenterate, "starfish" an echinoderm and "cray-fish" a crustacean.

On the contrary, the scientific names are fool-proof. Every animal has been provided with a scientific name. One scientific name always refers to one particular animal. The scientific names are international, *i.e.* they are used all over the world, irrespective of the language of the people. A Russian student of biology knows what exactly *Oryctolagus cuniculus* stands for and so does a Japanese or a German. The scientific names are given according to an internationally agreed system and they are usually descriptive, indicating some important feature of the animal. The scientific names also indicate relationship of animals with one another. The dog, wolf and jackal have the same scientific name *Canis*. It, therefore, implies that all these animals have certain common characters. The scientific names have yet another advantage. They are mostly derived from Greek and Latin, both of which are dead languages. This excludes the possibility of a change in the meaning of the names. In the case of living and growing languages the meanings of words are likely to change with time.

System of Scientific Names. Linnaeus has devised a system of giving scientific names to the animals. It is known as **binomial nomenclature,** meaning a system of double names. Under this system, each animal is given a name of two parts, *e.g. Panthera leo* is lion and *Panthera tigris* is tiger. The first part indicates the genus to which the animal belongs and is called the **generic name**. The second part refers to the species of the animal and is known as the **specific name**. Sometimes a species includes a few varieties. In such cases, the name of the variety follows the specific name so that the scientific name becomes **trinomial**, *e.g. Homo-sapiens europeus* is the name of the man of European race.

Rules for Scientific Names. Definite rules for giving scientific names to the animals were laid down by the International Commission on Zoological Nomenclature in 1901. These rules are summarized below :

Each animal is to be given a single scientific name of binomial system. In case several names have been given to an animal by different workers, the earliest name is to be considered valid. The scientific name should preferably be printed in italics. The generic name should always begin with a capital letter. The specific name should usually, not always, start with a small letter. The name of the variety, if present, should also commence with a small letter. The name of the author, in full or abbreviated, should follow the generic or specific name in technical descriptions, *e.g. Rana tigrina* Daud ; *Homo sapiens L.* (L. stands for Linnaeus. The names of the divisions above the genus are not printed in italics. They are, however started with capital letter.

Working of the Systems of Nomenclature and Classification. How the above systems of nomenclature and classification work can be best explained by a concrete example. Let us take the case of a dog which is a very familiar animal. There are several varieties of dogs like Alsation, Bull-dog, Grey-hound, Pekinese, Spaniel, etc. Though they differ from one another in form, size and colour, they all can be readily distinguished as dogs from other animals. They interbreed freely to produce fertile young. They, thus, belong to the same species and this is called *familiaris*. The dog resembles the wolf and the jackal in many respects. The specific names of these animals are *lupus* and *aureus* respectively. All the three, because of their similarities, have been assigned a common genus, namely, *Canis*. The full name of dog is, thus *canis familiaris*, that of the wolf *Canis lupus* and that of the jackal *Canis aureus*. Genera having some common characters are placed in one family. The genus *Vulpes*, which includes the foxes, shares some characters with the genus *Canis*. Both are, therefore, kept in the same family Canidae. The families which resemble one another are allotted the same order. The cat and its relatives, like lion, tiger and leopard, belong to the family **Felidae.** The bears form the family **Ursidae.** Since dogs, cats and bears are carnivorous animals, their families, viz. Canidae, Felidae and Ursidae respectively, are included in the same order called **Carnivora**. **Similar orders** are grouped together in the common class. **Thus,** the order Carnivora and several others like **Chiroptera** (bats), **Rodentia** (rats), **Cetacea** (whales), **Primates** (Apes, Man, etc.) are placed in the class **Mammalia,** because they all have mammary or milk glands. The classes having common features form the phylum. The fishes, frogs, lizards and birds are very different from the mammals and from one another. They are, therefore, assigned separate classes, namely, **Pisces**, **Amphibia**, **Reptilia** and **Aves**. But all these classes, have some common characters, *e.g.* the presence of a structure called the **notochord**. All these five classes are, therefore, included in a common phylum, **Chordata**. The phylum Chordata and all other phyla collectively constitute the **animal Kingdom** The complete classification of the dog and frog may be briefly expressed as under :—

Dog	**Frog**
Kingdom—Animalia	Kingdom—Animalia
Sub-kingdom—Metazoa	Sub-kingdom—Metazoa
Phylum—Chordata	Phylum—Chordata
Class—Mammalia	Class—Amphibia
Order—Carnivora	Order—Anura
Family—Canidae	Family—Ranidae
Genus—*Canis*	Genus—*Rana*
Species—*familiaris*	Species—*tigrina*

Principal Divisions of the Animal Kingdom. The animal kingdom is divided into three sub-kingdoms, namely, **Protozoa**, **Parazoa** and **Metazoa**. The sub-kingdom Protozoa includes a single phylum of the same name. The sub kingdom Protoza also includes a single phylum called **Porifera**. There is a difference of opinion among the zoologists regarding the number of phyla into which the sub-kingdom Metazoa should be divided. The more important phyla of this sub-kingdom are Coelenterata, Platyhelminthes. Aschelminthes, Annelida, Arthropoda, Mollusca, Echinodermata and Chordata.

TEST QUESTIONS

1. Why have the animals been given difficult scientific names when they already possess common names which are much easier ?
2. Explain the binomial system of naming the animals.
3. Name the various divisions used in the classification of animals. What is the study of classification called and why is it essential ?
4. What is natural classification ? Who is the founder of this classification ? Give the names of the principal phyla of the animal kingdom.
5. Give a suitable definition of 'species'. How would you classify the common dog ?
6. Enumerate the rules for scientific nomenclature.
7. Name the various systems of classification and show how they differ from one another. Which of these is the best and why ?
8. Give complete scientific names of at least ten animals and refer them to their classes and phyla.

Phylum Protozoa

(The First Animals)

I. Characteristics

The phylum protozoa includes the acellular or non-cellular organisms, which mark the beginning of animal life. They show the following characters :—

1. They have a simple microscopic body, consisting of a mass of protoplasm bounded by a protective membrane and containing one or more nuclei and a few other organelles.

2. They move by organelles like **pseudopodia**, **flagella** and **cilia**.

3. They often develop resistant cyst wall for perennation and dispersal.

4. All protozoa reproduce asexually by fission—binary, multiple or both.

5. Many forms reproduce sexually also by syngamy, *i.e.* fusion of gametes, or by conjugation.

6. The protozoa occur in the fresh and sea-water, in the moist earth, in the bodies of animals and plants and even in the air.

II. Classification

The phylum Protozoa is divided into two sub-phyla : **Plasmodroma** and **Ciliophora**. The sub-phylum Plasmodroma includes the Protozoa having a single nucleus or many similar nuclei. They possess pseudopodia or flagella for locomotion. Some lack locomotary organelles. The sexual reproduction, if present, occur by syngamy. This sub-phylum comprises three classes : **Mastigophora, Sarcodina** and **Sporozoa.** The sub-phylum Ciliophora includes the Protozoa which usually show nuclear dimorphism. The organelles of locomotion are cilia. The sexual reproduction occurs by **conjugation**. The sub-phylum comprises two classes : **Ciliata and Suctoria.**

Class 1. Mastigophora (Flagellata). The Mastigophora possess one or a few long whip-like structures, the **flagella**, for locomotion and capturing food. Asexual reproduction commonly occurs by longitudinal fission. The flagellates include free-living as well as parasitic forms. *Euglena viridis* and *Trypanosoma gambiense* are common examples.

Euglena viridis. *Euglena viridis* (Fig. 27.1) is a free-living, solitary, fresh-water flagellate. It has a spindle like body with a blunt anterior end and a pointed posterior end. The shape of the body is maintained

by a firm **pellicle**. The anterior end bears the **mouth** which leads into a short **gullet**. The latter opens into a rounded **reservoir**. A long flagellum arises from the wall of the reservoir by two roots and passes out through the mouth. Adjacent to the gullet there lies a small red spot, the **eye-spot** or **stigma**. It is sensitive to light. Near the reservoir is a large **contractile vacuole**, surrounded by a number of smaller contractile vacuoles. The **cytoplasm** contains conspicuous **nucleus** towards hind end, several radiating **chloroplasts** near the middle and numerous **paramylum bodies** scattered throughout. The chloroplasts contain **chlorophyll**, which

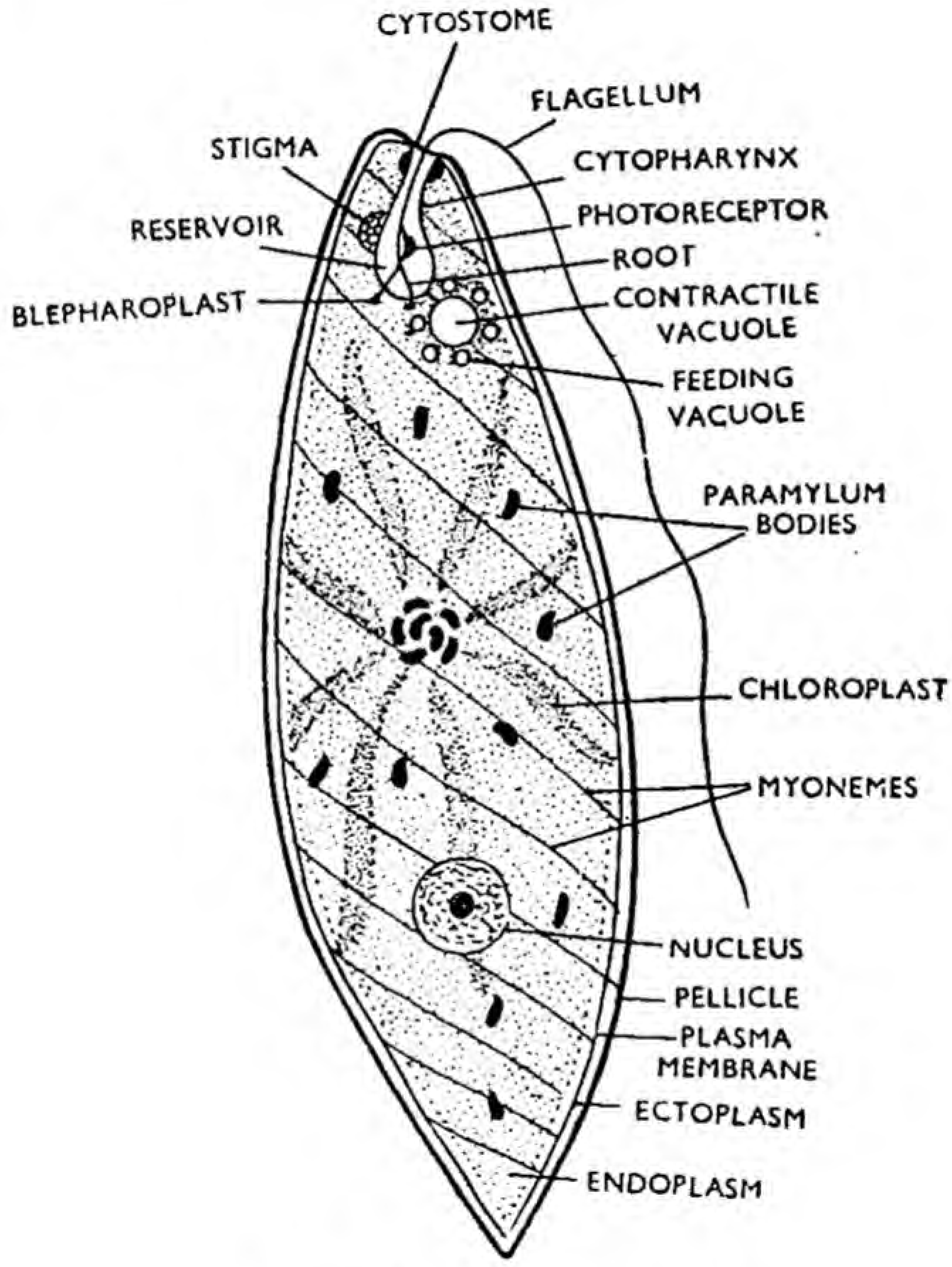


Fig. 27.1. *Euglena viridis*

imparts green colour to the organism and helps in the manufacture of food by photosynthesis. The paramylum bodies consist of carbohydrate resembling starch in nature.

Euglena swims in water by lashing movements of its flagellum. It also performs peculiar worm-like movements by local contractions and expansions in the body. These are called the euglenoid movements. Nutrition is mainly holophytic. It also absorbs some food dissolved in water. This is called **saprozoic nutrition**.

Trypanosoma gambiense. *Trypanosoma gambiense* (Fig. 27.2). is a parasitic flagellate. It lives in the blood of human beings and antelopes in certain parts of Africa. It does not produce any harmful effect on the antelopes which, thus serve as reservoir hosts. From the antelopes, it is carried to human beings by a blood-sucking insect, tse-tse fly (*Glossina palpalis* and *G. morsitans*). The waste materials produced by the parasites in the human blood cause **trypanosoma fever**. Later the parasites get into the **cerebro-spinal fluid** of the patient and produce a fatal disease called **African sleeping sickness,** in which the patient remains almost unconscious.

The adult has an elongated flattened, sinuous body tapering at both the ends. The anterior end is, however, more pointed than the posterior end. The body is enclosed in a firm pellicle and contains a single oval, centrally-placed, vasicular **nucleus** and scattered **volutine granules**. Mouth, contractile vacuole and food-vacuoles are absent. There is a single flagellum that arises from a minute granule, the **blepharoplast**, situated near the hind end of the body extends forwards along the free edge of a thin, irregular, rippling fold, the **undulating membrane** ; and then projects freely in front of the body, Just posterior to the blepharoplast is a relatively large body the **kinetoplast**. The two are connected by fine fibrils and often stain as one. The kinetoplast, blepharoplast and flagellum together form the kinetic apparatus.

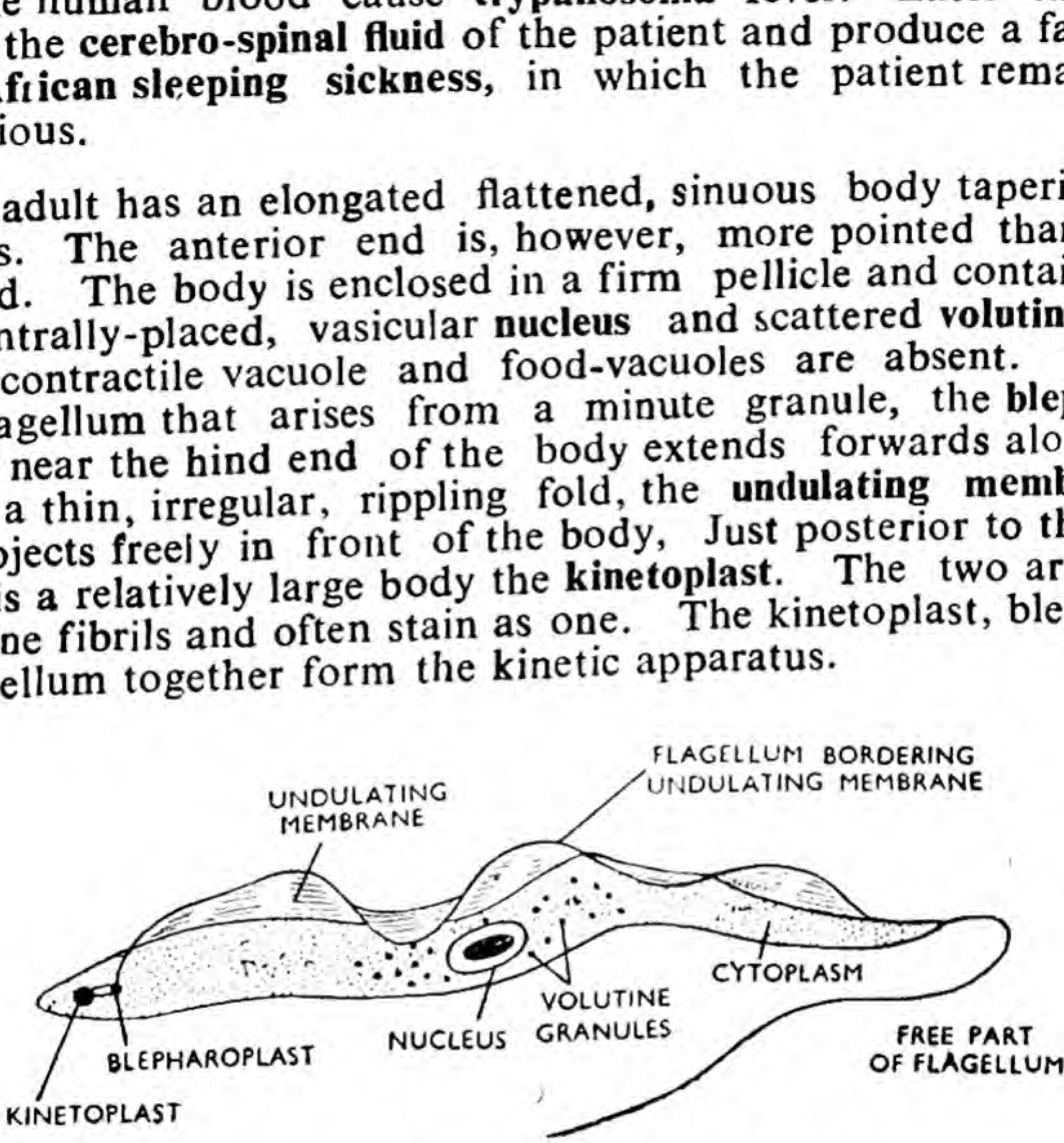


Fig. 27.2. *Trypanosoma gambiense*

The parasite absorbs food through the surface of the body. It swims with graceful wavy movement by the combined action of the undulating membrane and the flagellum. It reproduces by longitudinal binary fission which occurs in both the hosts involved in the life-history. No cysts are formed as the parasites are never outside a host.

Class 2. Sarcodina. The Sarcodina possess pseudopodia for locomotion and capturing food. They may be free living *e.g. Amoeba proteus* or parasitic, *e.g. Entamoeba histolytica.*

Amoeba proteus. *Amoeba proteus.* (Fig. 6.1) is described in detail in chapter 6.

Entamoeba histolytica. *Entamoeba histolytica* (Fig 27.3) inhabits the upper part of the large intestine of human beings all over the world.

Its cytoplasm show a sharp differentiation into clear ectoplasm and granular endoplasm. The latter contains a single nucleus and several food vocuoles. The nucleus is bounded by an extremely thin membrane having minute chromatin granules arranged in a layer on its inner surface and contains a small centrally placed karyosome, often surrounded by a clear area or hallo. The lobose pseudopodia have a characteristic glassy appearance as they are formed from ectoplasm. They are put out and withdrawn rapidly.

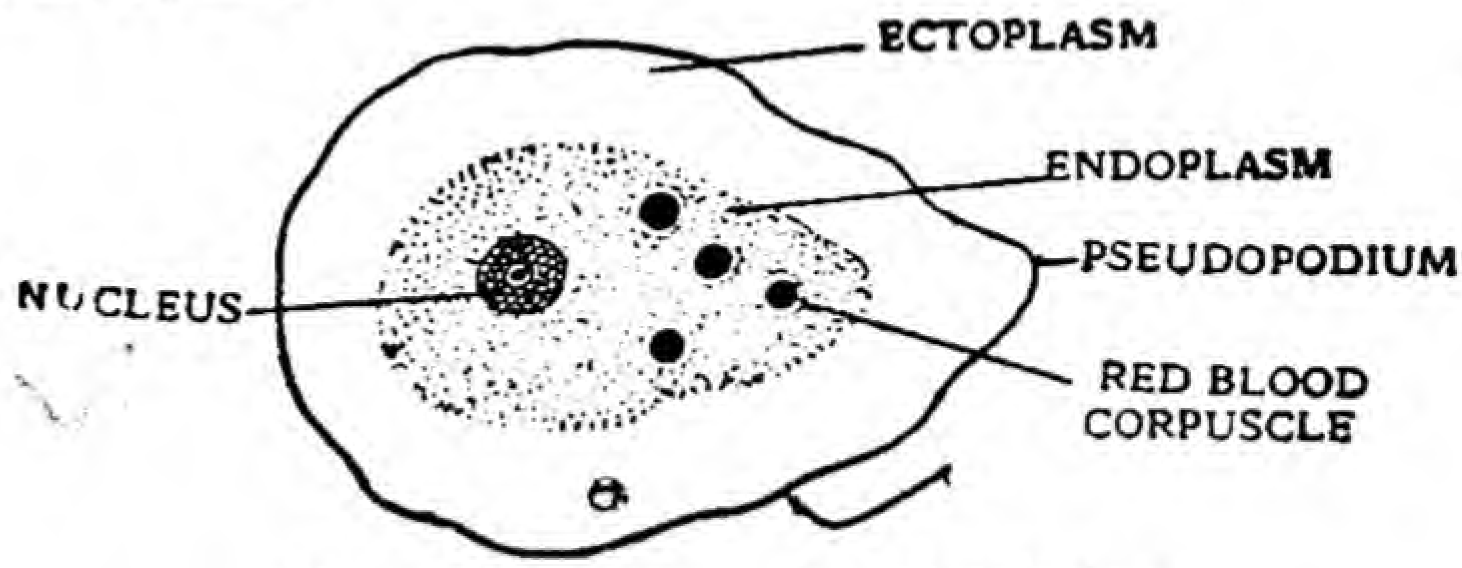


Fig. 27.3. *Entamoeba histolytica*

The parasite is chiefly holozoic. It is believed to produce a ferment called **cytolysin**, that dissolves the intestinal wall and liberates the blood. It takes red blood corpuscles and broken cells of the intestine. Some organic substances are also absorbed from the medium in a saprozoic manner. Respiration is probably anaerobic. Reproduction occurs by binary fission. Occasionally, it forms cysts that pass out in the faeces of the host. Inside cyst, the nucleus divides into four nuclei. Infection of healthy persons takes place by swallowing cysts in food and water. The cysts pass unaffected through the stomach and small intestine but in the large intestine hatch and release quadrinucleate parasites. The latter feed voraceously and very soon start a series of rapid divisions, resulting in uninucleate individuals.

The parasite causes **amoebic dysentery** or **amoebiasis** in which the patient passes out blood and mucus in the faeces and experiences pain in the abdomen. Ulcers develop in the intestine and in chronic cases intestinal wall is punctured. From the intestinal wall the amoebae may be carried in the blood stream to the liver, lungs, brain, etc. where abscesses may result.

Control of amoebiasis lies in proper sewerage disposal and well sanitated food and water supply.

Class 3. Sporozoa. The sporozoa lack locomotory organs. The mouth is absent. Nurition is saprozoic. Contractile vacuole is missing. Asexual reproduction takes place by multiple fission. Sexual reproduction also occurs. It is followed by spore formation, hence Sporozoa. All Sporozoa are parasitic. They infect all types of animals. The malarial parasite (*Plasmodium*) is a well-known example of this class. It is described in detail in chapter 7.

Class 4. Ciliata. The Ciliata have cilia for locomotion and capturing food. The mouth and gullet are usually present. Asexual

reproduction occurs by transverse binary fission. The sexual reproduction usually takes place by conjugation. The ciliates are found in abundance in fresh water as well as in sea-water. Some are parasites on man and other animals. The familiar example is *Paramecium*.

Paramecium. *Paramecium caudatum* (Fig. 8.) is described in detail in chapter 8.

Class 5. **Suctoria**. In Suctoria, the young (buds) bear cilia and swim about freely while the adults possess delicate protoplasmic outgrowths, the **suctorial tentacles**, and are usually fixed. The mouth and the gullet are absent. Nutrition is holozoic. Minute prey is captured and its protoplasmic fluid is sucked by the tentacles. Asexual reproduction occurs by budding. Sexual reproduction by conjugation also occurs in some forms. The Suctoria inhabit fresh and salt water. Some are parasitic, external or internal.

Podophrya. *Podophrya* (Fig. 27.4) is a common fresh water suctorian. It has a rounded body attached to a long stalk. The knobbed or suctorial tentacles arise from the entire surface of the body.

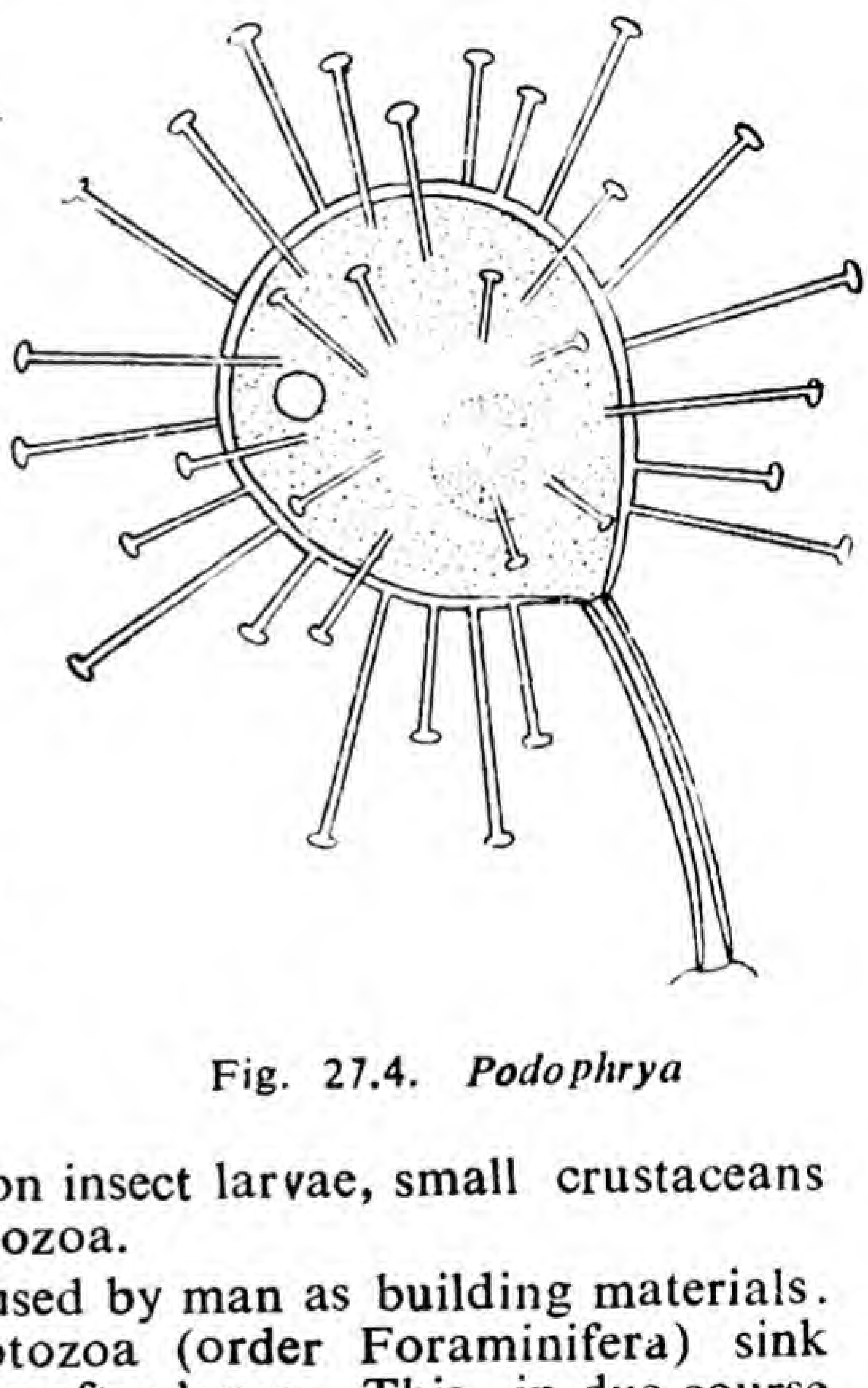


Fig. 27.4. *Podophrya*

III. Economic Importance

A. Protozoa are useful in the following ways :—

1. They aid in the production of human food. Many of the important food animals (fishes, crabs, lobsters, clams) live almost entirely on insect larvae, small crustaceans and worms which in turn feed on Protozoa.

2. They produce rocks which are used by man as building materials. The calcareous shells of marine Protozoa (order Foraminifera) sink down and collect on the sea bed layer after layer. This, in due course of time, leads to the formation of rocks. The limestone beds of Paris and Cairo have undoubtely been formed in this manner. Many buildings in Paris and the great Egyptian pyramids are built of stones carved out from these limestone beds.

3. They are employed in many biological and medical investigations, e.g. *Tetrahymena geleii* is used in nutritional research. The effects of various foods and poisons have been worked out on this organism.

4. They keep many harmful insects under check by inhabiting their bodies as parasites.

B. Protozoa are harmful in the following ways :—

1. Many Protozoa live in the soil and feed on nitrogen-fixing

bacteria. This decreases the production of nitrates and reduces soil fertility.

2. Some Protozoa render the water of reservoirs unfit for drinking by giving it an unpleasent smell. For example, *Uroglenopsis* imparts to water a fishy odour resembling that of cod-liver oil. The disagreeable smell is due to the aromatic oils produced by Protozoa.

3. Certain Protozoa parasitize human body and cause serious disease, *e.g. Entamoeba histolytica* produces amoebic dysentery. *Plasmodium* brings about malaria. *Trypanosoma gambiense* results in sleeping sickness in Africa, etc. Parasitic Protozoa also attack useful animals like fishes, poultry, rabbits, pigs, cattle, etc. and indirectly affect man's economy.

IV. Summary

Phylum **Protozoa** (pro-to-zo-a) : Acellular animals.

Sub-phylum (*a*) **Plasmodroma** (plaz-mo-dro-ma) : With pseudopodia or flagella or both or none.

Class 1. **Mastigophora** (mas-tig-o-for-a) : With flagella, *e.g. Euglena, Trypanosoma.*

Class 2. **Sarcodina** (sar-ko-dy-na) : With pseudopodia, *e.g. Amoeba Entamoeba.*

Class 3. **Sporozoa** (spor-o-zo-a) : With spores, *e.g. Plasmodium.*

Sub-phylum (*b*) **Ciliophora** (sil-ee-o-for-a) : With cilia.

Class 1. **Ciliata** (sil-ee-ay-ta) : With cilia throughout life, *e.g. Paramecium.*

Class 2. **Suctoria** (suc-to-ri-a) : With cilia in the young and tentacles in the adult, *e.g. Podophrya.*

TEST QUESTIONS

1. Give the characters of phylum Protozoa ? Name its classes and show how they differ from each other. Give at least one example of each class.

2. Place the following animals in their natural position in the animal kingdom. Also write short notes on them.

Entamoeba histolytica, Trypanasoma gembiens, Euglena viridis, Podophrya.

3. Discuss the economic importance of Protozoa.

CHAPTER 28

Phylum Porifera

(The Sponges)

I. Characteristics

The phylum porifera includes the sponges. The sponges show the following characters.

1. They are multicellular animals with low organization.

2. Their body bears numerous pores, the **ostia**, that lead into a large cavity, the **paragastric cavity**, either directly or through a system of canals. The paragastric cavity opens out by one or more larger apertures, the **oscula**, which usually lie at a higher level than the ostia. A constant current of water enters the paragastric cavity through the ostia and leaves it through the oscula. This current is nutritive, respiratory and excretory in function. It brings food and oxygen and carries away waste materials.

3. The digestion is intracellular.

4. The body-wall of a sponge consists of two layers of cells. The outer layer is formed of thin flat cells. The inner layer is formed either entirely of flagellated collar cells, the **choanocytes**, or of flagellated collar cells at certain places and flat cells at others. Between these layers lies a gelatinous **mesenchyme** containing free cells or **amoebocytes** of many kinds. Much of the vital activity is performed by the free cells independently.

5. There are no organs, movable parts and appendages in the sponges.

6. The body is usually supported by an internal skeleton of **spicules** or **spongin fibres** or both.

7. The sponges reproduce asexually by budding and **gemmules**.

8. Sexual reproduction occurs by the formation of eggs and sperms.

9. There is a free-swimming ciliated larval stage in development for dispersal.

10. All the sponges are aquatic, the majority being marine, a few freshwater. They grow attached to various objects in water. They resemble the plants in appearance and were actually regarded as such in the past.

They are not in the direct line of evolution. They are remnants of a side branch that separated from other multicellular animals at a very early stage. They have remained in their primitive condition and have not given rise to any higher types of animals. There, thus, seems to be no phylogenetic relationship between the sponges and

other many-celled animals. For this reason, the sponges are assigned to a separate sub-kingdom called **Parazoa**.

II. Advancement

The sponges show advancement over the protozoans in having—

(*i*) a multicellular body,
(*ii*) division of labour among the cells,
(*iii*) spermatozoa and ova in sexual reproduction, and
(*iv*) segmentation in the development of the zygote.

III. Classification

The phylum Porifera is divided into three classes : Calcarea, Hexactinellida and Demospongia.

Class 1. Calcarea (Calcispongiae). The Calcarea have skeleton of calcareous spicules, *e.g. Grantia* (Fig. 28.1).

Fig. 28.1 *Grantia*

Class 2. Hexactinellida (Hyalospongiae). The Hexactinellida have skeleton of 6-rayed siliceous spicules, *e.g.* Venus' flower basket.

Class 3. Demospongia. The Demospongia have skeleton of 1—4 rayed siliceous spicules or of spongin or of both, *e.g.* bath sponge.

IV. Economic Importance

The sponges are of very little economic value. The flexible spongin skeleton of the marine sponge *Euspongia*, after the removal of living tissues, forms the bath sponge of commerce. The siliceous skeleton of the Venus' flower-basket is ornamental. *Cliona* or the boring sponge is harmful. It grows on the shells of useful mollusks like oysters and clams and kills them by boring holes in the shells.

V. Summary

Phylum **Porifera** (pore-if-er-a). : Two-layered body with pores.

Class 1. **Calcarea** (Kal-ke-ri-a) : Spicules calcareous, *e.g. Grantia.*

Class 2. **Hexactinellida** (hex-ak-ti-nel-i-da) : Spicules siliceous and 6-rayed, *e.g.* Venus' Flower Basket.

Class 3. **Domospongia**. (dem-o-sponge-i-a) : Skeleton of spongin fibres or of spongin fibres and siliceous spicules, *e.g.* bath sponge.

TEST QUESTIONS

1. Enumerate the important characters of the Phylum Porifera. Name the various classes of this phylum, giving at least one example of each.

2. Discuss the economic importance of the sponges. Why have they been separated from other multicellular animals ?

CHAPTER 29

Phylum Coelenterata

(The Two-layered Animals)

I. Characteristics

The phylum Coelenterata includes the hydroids, jelly-fishes, sea-anemones, corals, etc. These animals possess the following characters :—

1. They usually have a radial symmetry.

2. The body encloses a single cavity, the coelenteron or gastro-vascular **cavity**.

3. The digestion is partly intercellular and partly intracellular. The coelenteron opens to the exterior by a single aperture, the mouth, which works both for the intake of food and elimination of the indigestible residue.

4. The coelenterates are mostly **diploblastic** animals. Each of the two body-layers, namely, the epidermis and gastrodermis, contains several types of cells. There are special stinging cells, cnidoblasts, in one or both the true layers of the body.

5. Respiration takes place through the general body surface.

6. The excretory and circulatory organs are lacking.

7. The individual may be cylindrical when it is called a **polyp** or umbrella-like in which case it is known as a **medusa**. Either or both the forms may be found in the same animal. The polyp in all cases is fixed but may be solitary or colonial. The medusa on the other hand, is always free-swimming and solitary.

8. Reproduction is usually asexual (budding) in the polyp and sexual in the medusa.

9. The development is accompanied by a free-swimming ciliated larva, the planula.

10. The coelenterates are chiefly marine.

II. Advancement

The coelenterates show advancement over the sponges in having :—

(*i*) Definite form and symmetry,

(*ii*) Well organized layers of cells in the body-wall,

(*iii*) Muscular and nervous tissues, and

(*iv*) A digestive cavity.

III. Classification

The phylum Coelenterata is divided into three classes : **Hydrozoa, Scyphozoa** and **Actinozoa.**

Class 1. Hydrozoa. The Hydrozoa exist as polyps or medusae or both. In the latter case, which is more common, there is a distinct alternation of generations between the asexual polyp form and the sexual medusa form. The mouth leads directly into the gastrovascular cavity lined by gastrodermis, there being no stomodaeum lined by epidermis. The gastrovascular cavity is a wide undivided space in the polyps. The medusae have a circular inwardly-projecting shelf, the velum, around its edge. The mesogloea is noncellular. The gonads are epidermal in origin and the gametes are shed directly into the surrounding water. The Hydrozoa may be solitary or colonial, fixed or free swimming. The important examples are *Hydra*, *Obelia* and *Physalia*,

Hydra. *Hydra* (Fig. 9.1) is a solitary and fresh-water form. It is described in detail in chapter 9.

Obelia. *Obelia* (Fig. 10.2) is a colonial, and marine form. It is described in detail in chapter 10.

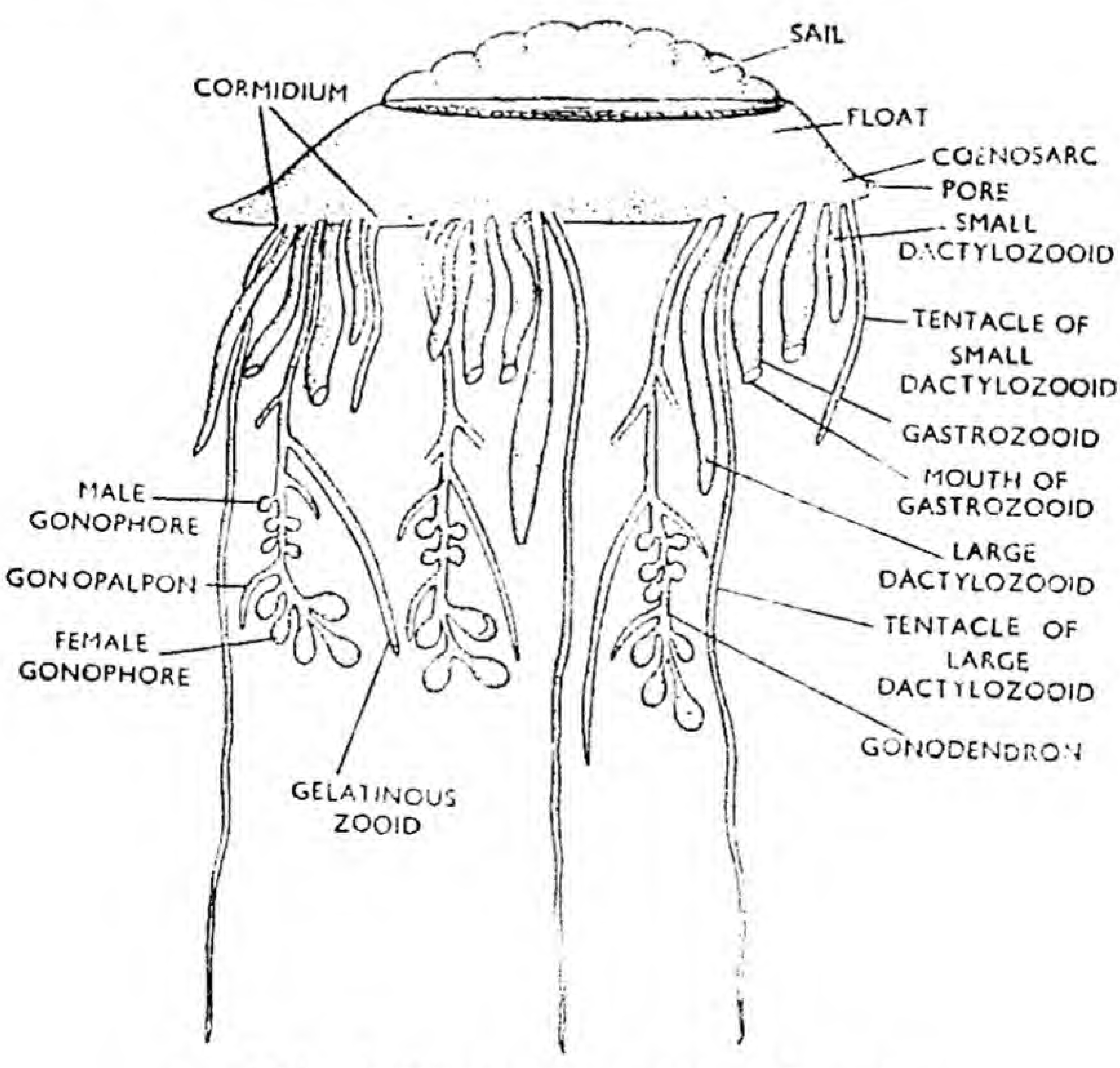


Fig. 29.1. Portuguese-man-of-war (*Physalia*)

Physalia. *Physalia* (Fig. 29·1), popularly called the Portuguese man-of-war, is found floating on the surface of tropical seas. It has a large, oval, bright blue, balloon-like **float** or **pneumatophore** with a contractile crimson **crest** or **sail** at the top. The float may be up to 30 cm. in length and its crest up to 12 cm. long. The float bears on the floor a **gas gland** that secretes gas to keep the float inflated. The gas contains 85-91% nitrogen, 7·5 to 13·5% oxygen and 1·5% argon. The pneumatophore supports the colony and also keeps it afloat.

On the undersurface of the float is a flattened disc-like **coenosarc** which buds off individuals, the **zooids** or **persons**. The latter hang down and occur in clusters called **cormidia**. A cormidium includes **gastrozooids, dactylozooids** and **blastostyles**. The gastrozooids have the usual polyp form with a mouth but lack tentacles. They feed the colony. The dactylozooids are like the gastrozooids in form but lack mouth and each bears a tentacle at the base. They are of two types : **small** and **large**. The tentacle of the latter is very long (up to 15 m.) and bears a twisted ribbon beset with nematocysts. The dactylozooids protect the colony and also help in capturing the prey. The blastostyles are branched and are termed the **gonodendra**. They bear three types of structures : clusters of **gonophores** that develop gonads on them, leaf-like **gonopalpons** that protect the gonophores, and peculiar **gelatinous zooids** of unknown function. The gonophores are dioecious. The male gonophores are reduced, develop on the proximal part of the gonodendra and are not set free. The female gonophores are medusa-like, develop on the distal part of the gonodendra and are set free.

Physalia colony is carried from place to place by currents in water or by winds blowing against the pneumatophore. Though an animal of the open sea, it is occasionally drifted to and thrown on the shore by waves in large numbers where it dies. The prey (fishes, crustaceans, etc.) is caught and paralysed by the tentacles which then contract to bring it to the gastrozooids. The latter receive the prey in a digestive sac formed by spreading their lips over it. The poison of its nematocysts is very dangerous to man. It affects the nervous system and is, thus, a **neurotoxin**. A fish *Nomeus* lives as a commensal among the tentacles of *Physalia*. This fish comes out, catches a food animal and quickly goes back among the tentacles to devour it in a safe atmosphere. The parts of the prey not taken by the fish are captured by *Physalia*. This fish also lures predaceous fishes towards the tentacles which at once capturs them. In return, *Physalia* protects the fish from enemies with its nematocysts.

The gastrozooids, dactylozooids, blastostyles and gonopalpons are modified polyps while the gonophores and the pneumatophore are modified medusae.

Class 2. Scypozoa. The Scyphozoa exist predominantly in the medusa form. There is no stomodaeum. The gastrovascular cavity is divided into pouches. There is no velum. The mesogloea has some

cells in it. The gonads are gastrodermal in origin and the gametes are shed in the gastrovascular cavity whence they pass out through the mouth. The Scyphozoa are all marine. They are solitary and chiefly free-swimming. They are called jelly-fishes.

Aurelia. *Aurelia* (Fig. 29.2) is the common jelly-fish. It has a soft, white or bluish, saucer-like body with 4 pink horseshoe-shaped gonads. The central four-sided mouth is surrounded by four long tapering oral arms. The margin of the saucer bears numerous small tentacles. *Aurelia* floats near the surface of the sea, either singly or in shoals. It can swim by the rhythmic contractions of its body but is largely carried by the waves. It feeds on crustaceans, small fishes, etc. The prey is seized and paralysed by the stinging cells on the oral arms which then carry the victim to the mouth.

Class 3. Actinozoa (Anthozoa). The Actinozoa exist only as polyps that look ike flowers. The medusa form is entirely absent and there is no alternation of generations. Mouth leads into a stomodaeum lined by epidermis. The gastrovascular cavity is divided into chambers by

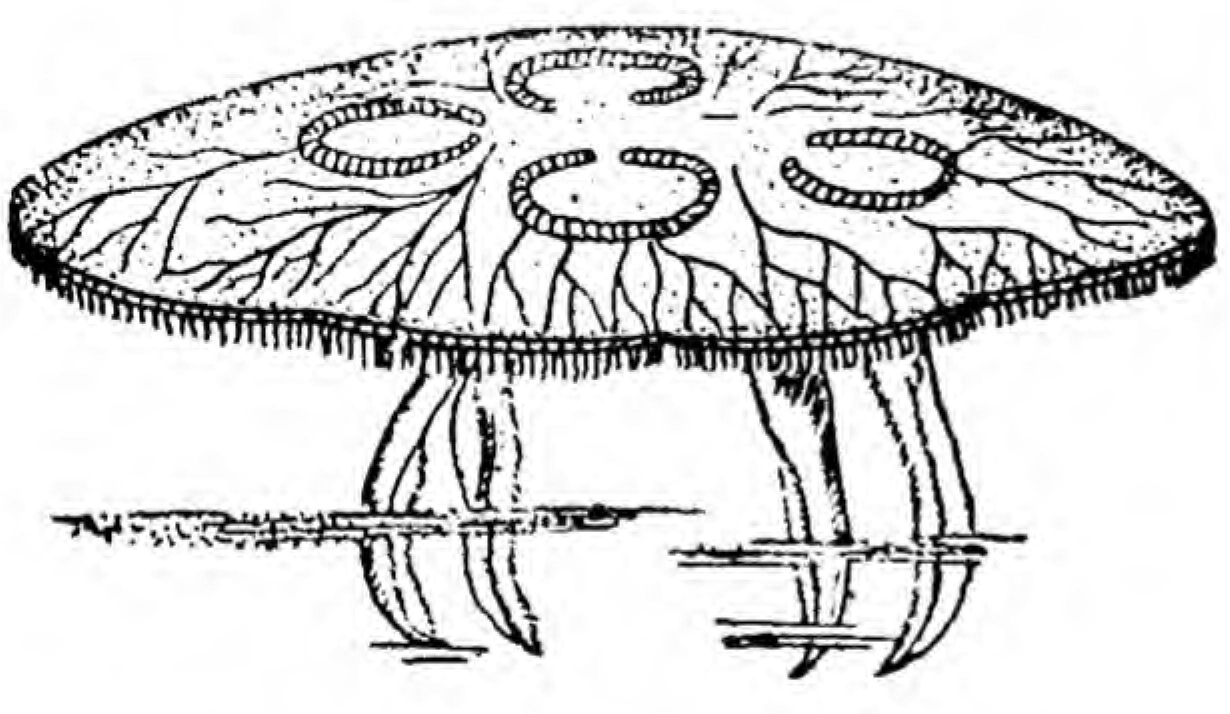


Fig. 29.2. A jelly-fish (*Aurelia*)

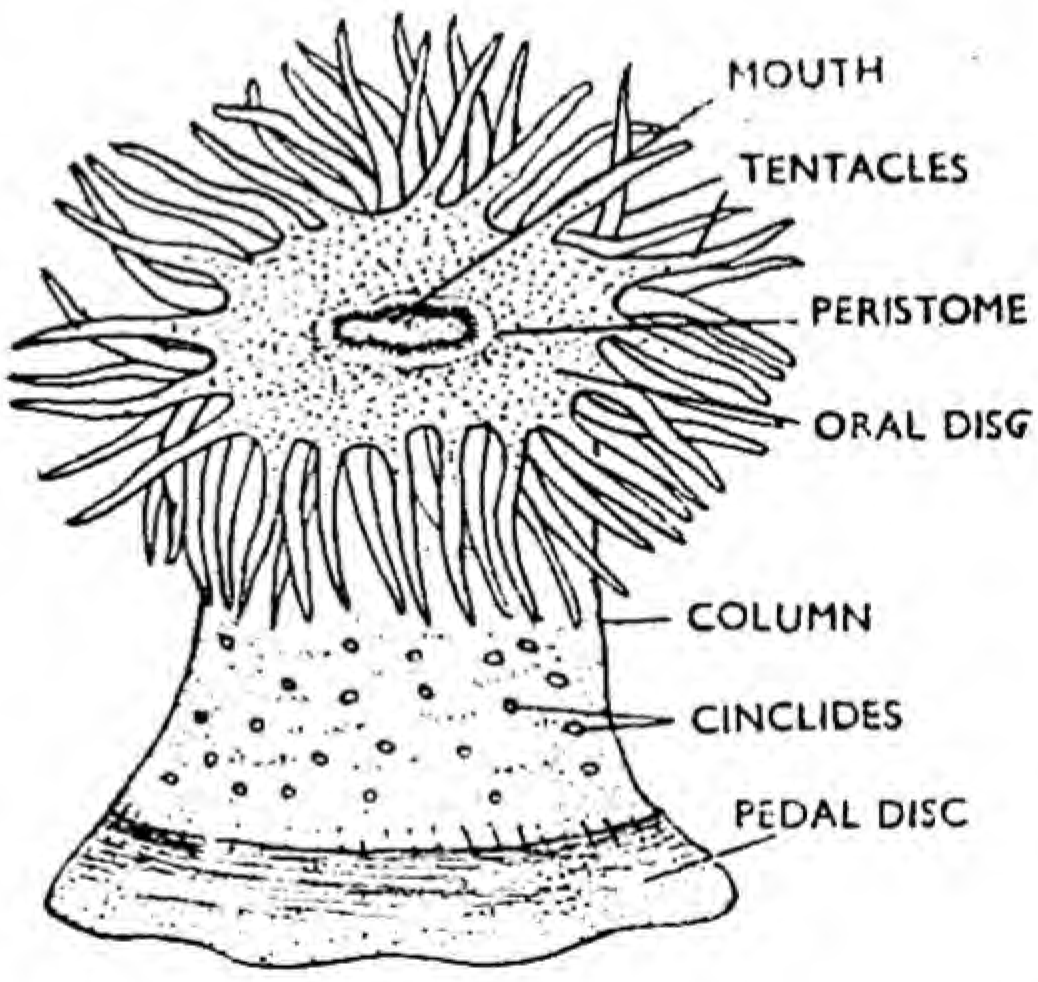


Fig. 29.3. Sea-anemone (*Metridium*)

vertical septa, the **mesenteries.** The mesogloea is in the form of connective tissue consisting of fibres and cells in the matrix. The gonads are gastrodermal in origin and the sex cells are shed into the gastrovascular cavity whence they escape out through the mouth. The Actinozoa are all marine and fixed. They may be solitary or colonial. The common examples are sea anemone, mushroom coral, star coral, sea-pen and sea-fan.

Sea-anemone. The sea-anemone (Fig. 29.3) is a solitary polyp found attached to rocks in the shallow coastal waters of almost all the seas. It has a soft cylindrical body with a crown of tentacles arranged in several

rings round the mouth. It can contract and expand its body and tentacles to a great extent. It can also slowly creep on the substratum.

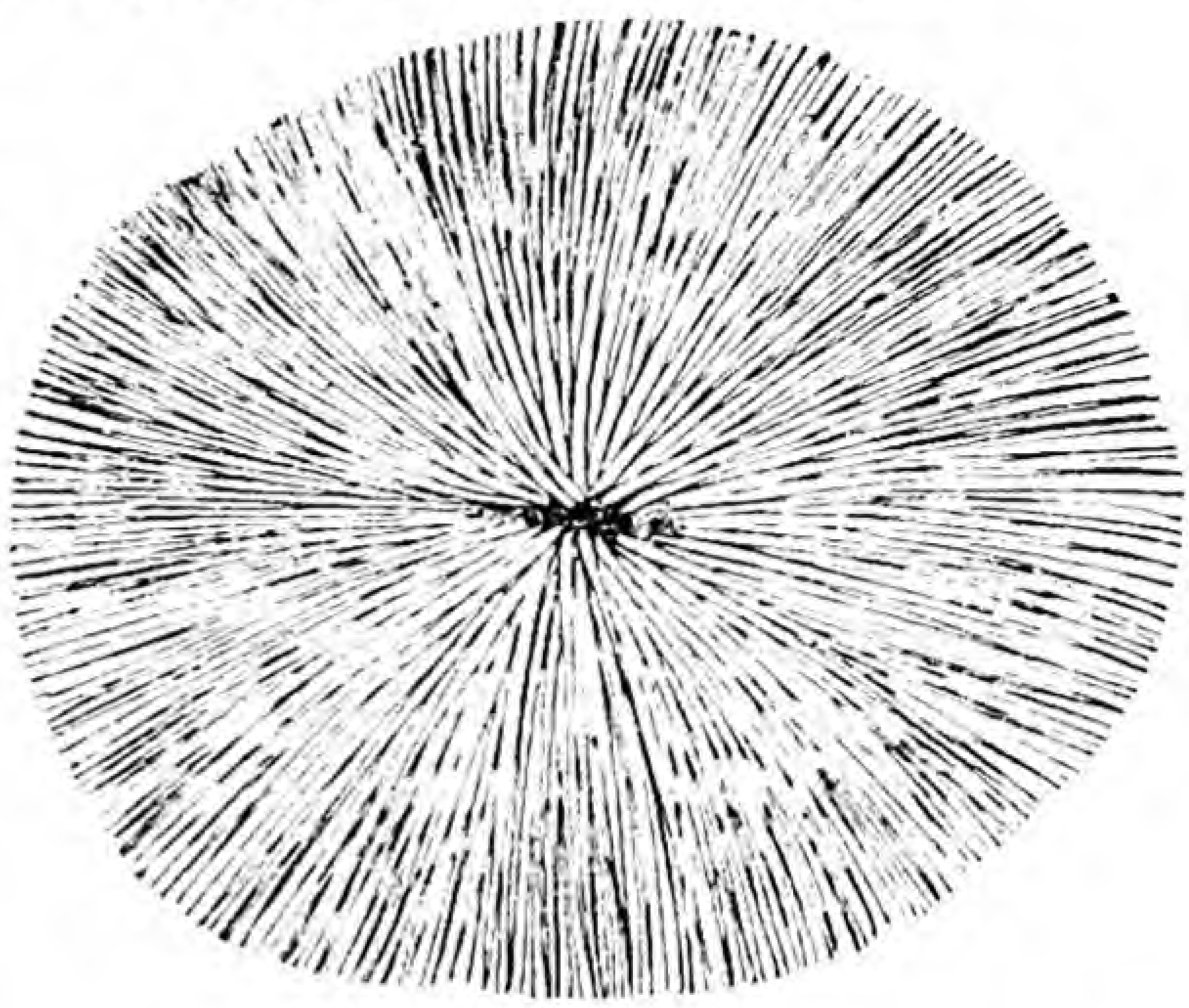


Fig. 29.4. Mushroom coral (*Fungia*)

The sea-anemones are sometimes attached to the gastropod shells inhabited by hermit-crabs. The crabs carry the sedentary anemones to new places and share their food with them. In return, the anemones protect the crabs from their enemies with the stinging cells. This mutually beneficial association of two organisms is called **commensalism**.

Mushroom Coral. The mushroom coral (Fig. 29.4) is also a solitary form. It secretes round itself a calcareous skeleton, called **corallite**, which has the form of a disc with concave base and convex upper surface that bears a number of thin radiating septa. It inhabits tropical seas.

Star-Coral. The star coral (Fig. 29.5) is a colonial coelenterate. The colony grows on rocks and shells in sheltered places in the tropical seas. It consists of a large number of polyps produced by budding. Each polyp looks like a small sea-anemone. All the polyps in the colony secrete calcareous skeleton round them for protection. Their skeletons coalesce and the colony presents the appearance of a stone, the **corallum**. The polyps protrude through pores in the corallum.

By the gradual accumulation of the skeletons of the tiny coral polyps, enormous masses, called **coral reefs**, are formed in the course of centuries. The 1,350 miles long Great Barrier Reef of Australia and the Laccadive and Maldive Islands of Indian Ocean are coral constructions.

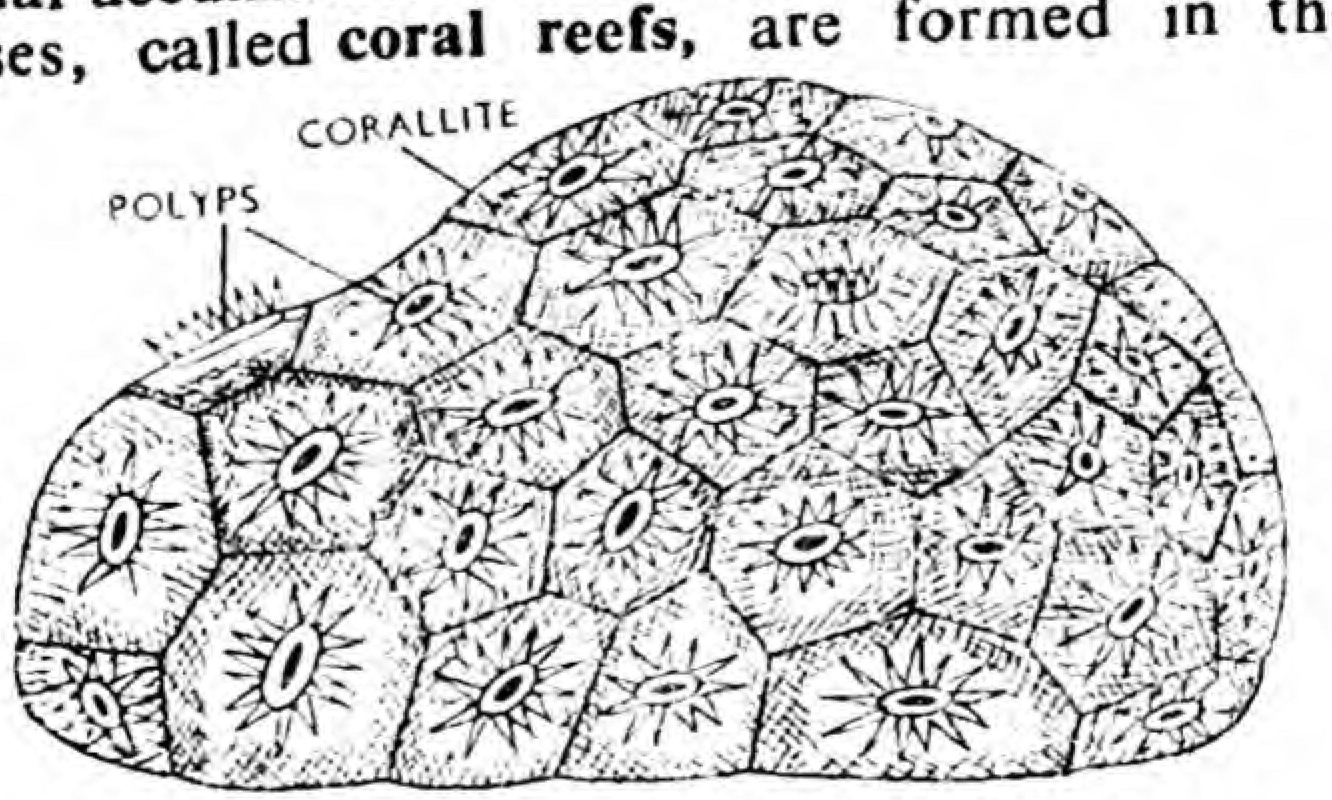


Fig. 29.5. Star coral (*Astrangia*)

Sea-Pen. The sea-pen (Fig. 29.6) is also a colonial form. The primary colony is fleshy, phosphorescent, upright and feather-like. The primary

zooid is greatly elongated vertically and is supported internally by a horny skeletal rod. It is differentiated into two parts : the lower **stalk or peduncle** and the upper **rachis**. The peduncle is embedded in the sand or mud and serves to fix the colony. The rachis is flattened

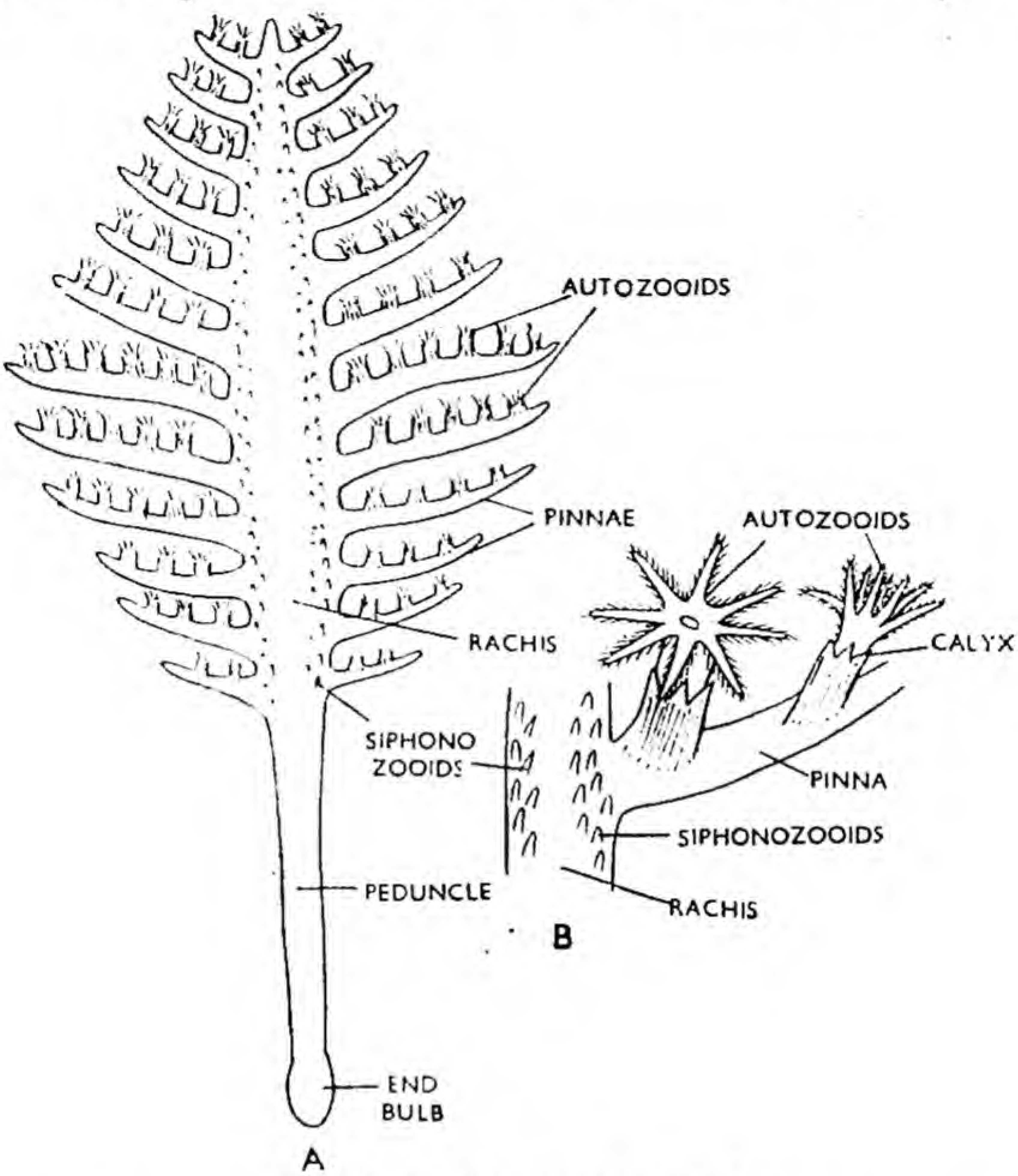


Fig. 29.6. Sea-pen (*Pennatula*)

and bilaterally symmetrical. It bears lateral branches, the **leaves or pinnae**, each producing on its upper surface a single row of normal zooids, the **feeding zooids** or the **autozooids**. Modified tentacle-less zooids, termed the **siphonozooids**, grow on the dorsal surface and lateral sides of the rachis. These zooids serve to drive a current of water through the colony. *Pennatula* is, thus, a dimorphic coelenterate.

Sea-fan. The sea-fan (Fig. 29.7) is also a colonial animal. The colony is erect and tree-like. It consists of a basal **plate** that fixes it into the sand or mud, a short **main trunk** and a number of slender **stems** that arise from the trunk and are repeatedly branched. All the branches are in one plane and anastomose, forming a fan-like net-work. The colony is supported by a flexible horny rod and calcareous spicules. The colony is beset with pores through which zooids can partly protrude.

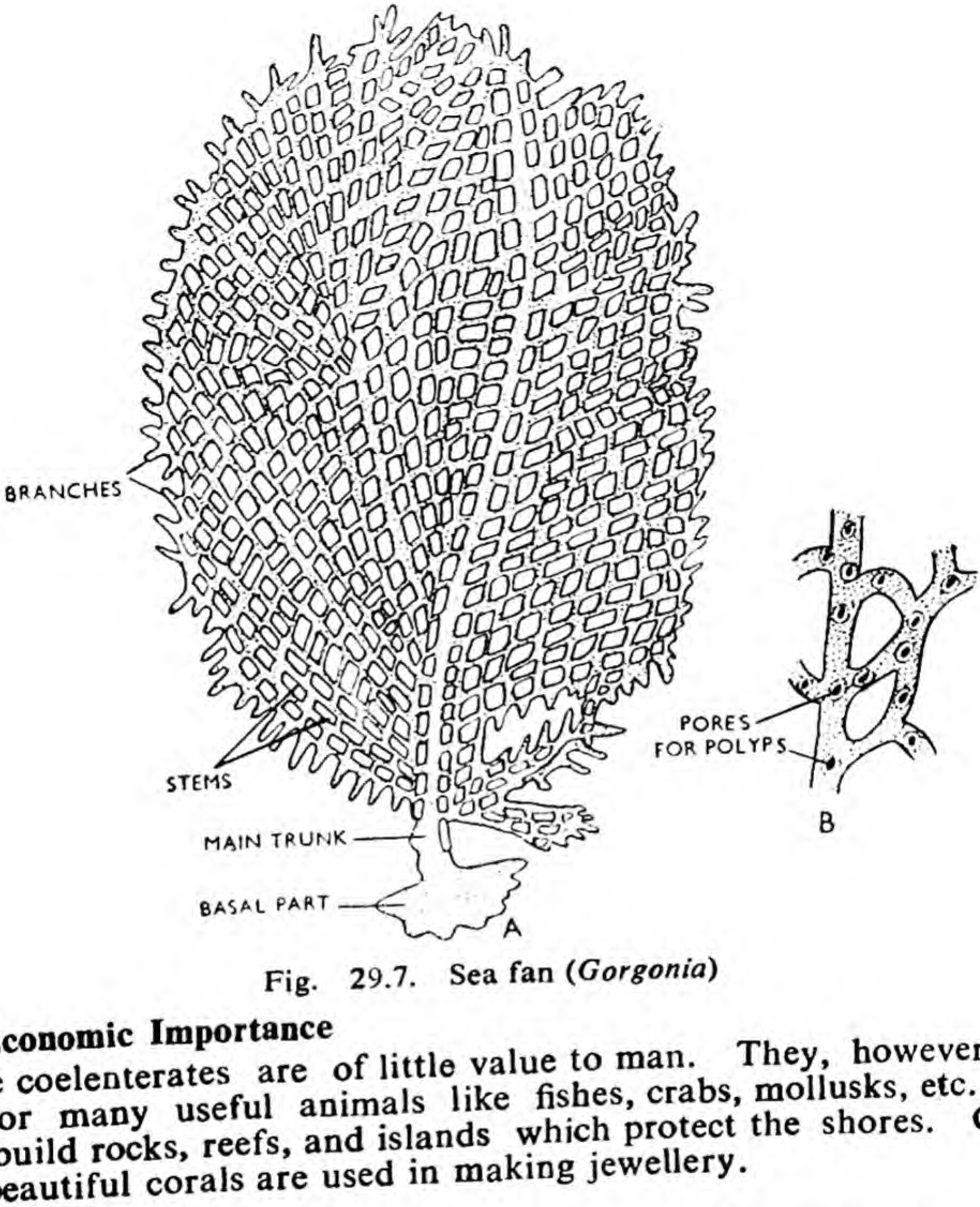


Fig. 29.7. Sea fan (*Gorgonia*)

IV. Economic Importance

The coelenterates are of little value to man. They, however, form food for many useful animals like fishes, crabs, mollusks, etc. The corals build rocks, reefs, and islands which protect the shores. Certain more beautiful corals are used in making jewellery.

V. Summary

Phylum **Coelenterata** (se-len-ter-y-ta) : Two-layered sac-like body, having a single cavity with one opening.

Class 1. **Hydrozoa** (hy-dro-zo-a) : With both polyp and medusa form, *e.g. Hydra, Obelia, Physalia.*

Class 2. **Scyphozoa** (sy-fo-zo-a) : With only medusa form, *e.g. Aurelia.*

Class 3. **Actinozoa** (ak-tin-o-zo-a) : With only polyp form, *e.g.* anemone, coral, sea-fan, sea-pen.

TEST QUESTIONS

1. Make a list of the distinguishing features of the phylum Coelenterata. Give a brief classification of the phylum. Mention at least two examples of each class.
2. Classify the following animals and write a brief ecological note on each: *Hydra, Physalia, Aurelia,* Sea-anemone, Coral, Sea-fan, Sea-pen.

CHAPTER 30

Phylum Platyhelminthes

(The Flat worms)

I. Characteristics

The phylum platyhelminthes includes the planarians, flukes and tape-worms. They show the following characters :—

1. They have a bilateral symmetry.

2. The body is unsegmented and usually flattened dorsoventrally.

3. It develops from three germ-layers, namely, ectoderm, mesoderm and endoderm. The flat worms are, therefore, called **triploblastic** animals in contrast to diploblastic animals like coelenterates.

4. There is no body-cavity or coelom. The space between the body-wall and the internal organs is filled by a loose connective tissue called **parenchyma.**

5. Digestive system, when present is **incomplete,** *i.e.* it has mouth but lacks anus.

6. There are well-developed muscle layers, circular and longitudinal, in the body-wall.

7. Excretory system includes characteristic **flame cells** connected with excretory ducts that lead to the exterior.

8. Nervous system comprises the anterior brain and 1 to 3 pairs of longitudinal nerve-cords

9. The skeletal, circulatory and respiratory systems are undeveloped.

10. The flat worms are usually hermaphrodite. The gonads lead to the exterior by reporductive ducts.

11. The development may be direct or with larval stages.

12. Asexual reproduction occurs in certain forms.

13. The flat worms are both free-living and parasitic.

II. Advancement

The platyhelminthes show advancement over the coelenterates in having—

(*i*) bilateral symmetry,

(*ii*) mesoderm,

(*iii*) brain and nerve-cords in the nervous system,

(*iv*) muscle-layers,

(*v*) excretory system and

(*vi*) reproductive ducts.

III. Classification

The phylum Platyhelminthes is divided into three classes : **Turbellaria, Trematoda** and **Cestoda**.

Class 1. Turbellaria. The Turbellaria are mostly free-living and are found in fresh-water, sea-water, green-houses and moist soil. A few are parasitic also. They are covered with a delicate ciliated epidermis. The cilia help in locomotion. The mouth is usually ventral. The digestive tract is often present. The development is direct.

Dugesia. *Dugesia* is a common turbellarian (Fig. 30.1). It is a fresh-water form. It avoids light. It glides over a self-secreted tract of mucus by backward strokes of the cilia present on the ventral surface. It feeds on small crustaceans. It reproduces asexually by transverse fission and has a great power of regeneration.

Dugesia has an elogated dark-brown body. Its broad anterior end bears a pair of **eyes** and forms the head. The **mouth** lies in the middle of the ventral side. The genital aperture lies behind the mouth.

Class 2. Trematoda. The trematodes are commonly called the **flukes.** They are parasitic on or in the vertebrates. They are without cilia.

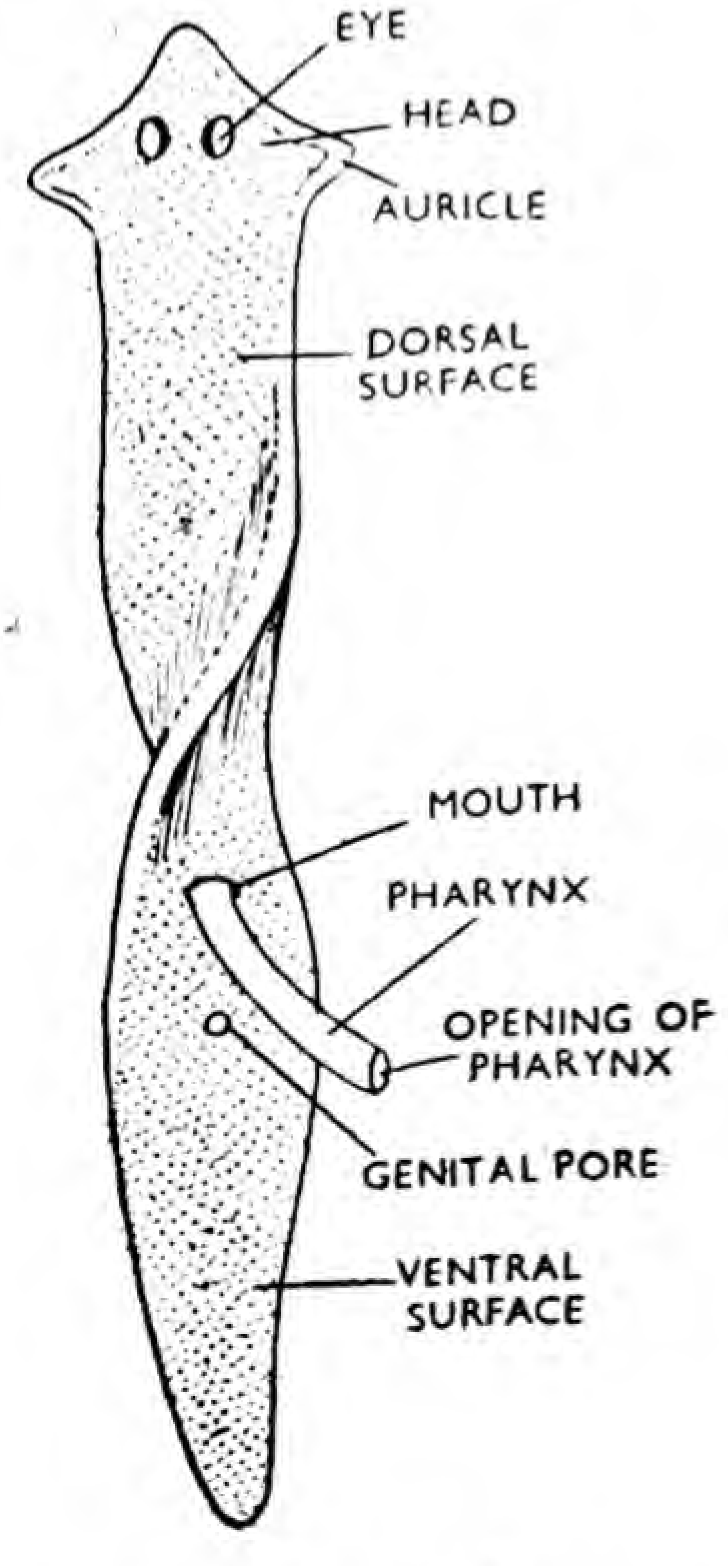


Fig. 30.1. *Dugesia*

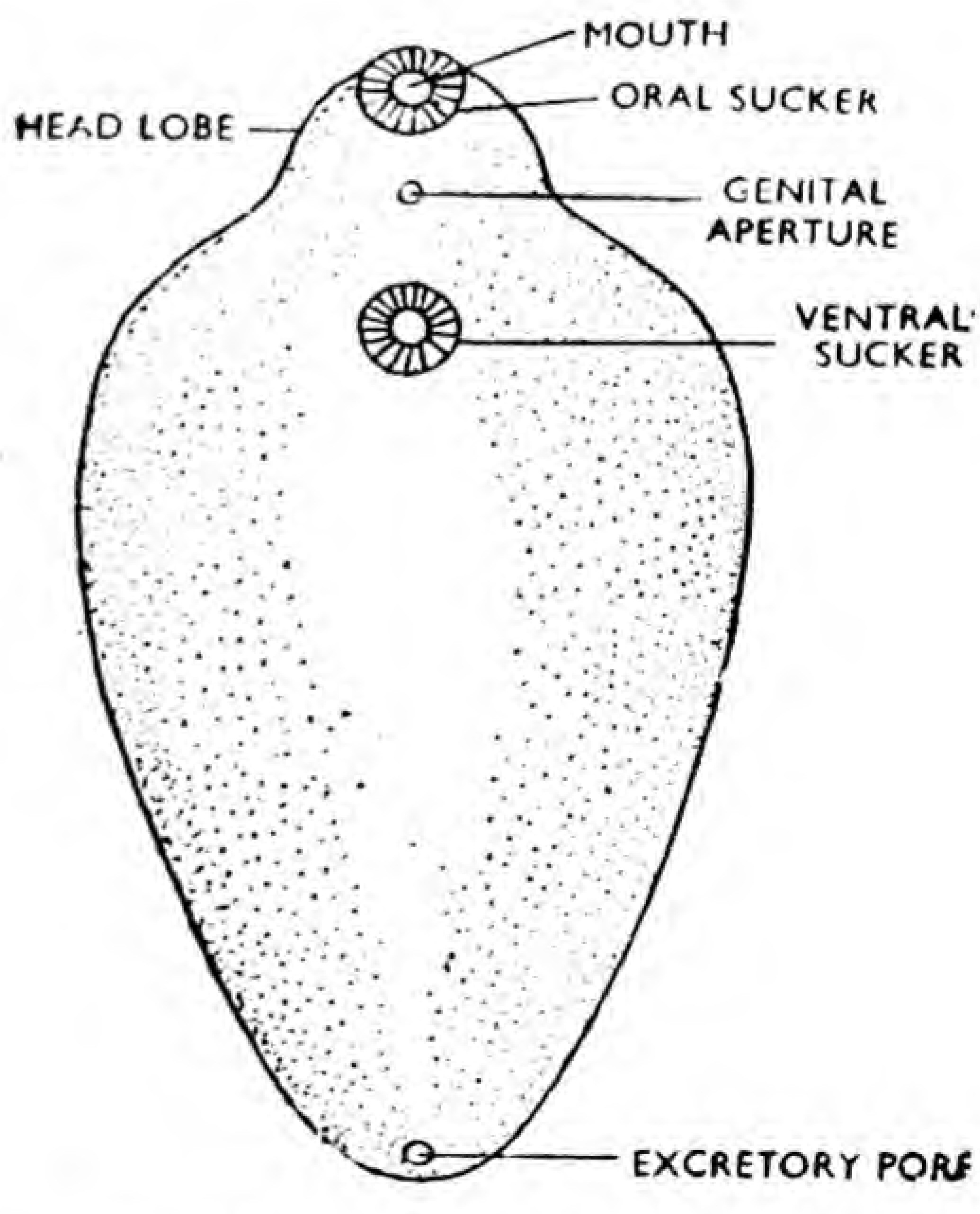


Fig .30.2. Liver-fluke (*Fasciola*)

The body is covered with thick cuticle. They have suckers for attachment to the host. The mouth is anterior in position. The digestive tract is present. The adults lack sense organs. Life-history includes several larval forms that live in an intermediate host. Liver-fluke and blood-fluke are the familiar examples.

1. Liver-fluke. The common liver-fluke is *Fasciola hepatica* (Fig. 30.2).

(*i*) **Habitat**. *Fasciola hepatica* lives in the bile-ducts of the liver of sheep and goats. It is also found in other mammals, particularly in cattle, and occasionally in man.

(*ii*) **Habits.** The worm feeds in the liver on bile, blood and cells. The food is ingested through the mouth by sucking action. The indigestible matter is also eliminated through the mouth.

(*iii*) **External Characters**. The adult worm has a flat, dark-brown, leaf-like body. It measures about 25 mm. in length and 12 mm. in breadth. The maximum width is about the anterior third of the body. At the front end there is a small conical projection called the **head lobe**. The latter bears the **mouth** at its tip. There are two suckers. One of these surrounds the mouth and is known as the **oral sucker**. The other lies on the ventral side a little behind the head lobe. It is called the **ventral sucker** or **acetabulum**. It is cup-shaped and serves for attachment in the bile-ducts. Between the two suckers, on the ventral side, is a small aperture, the **genital pore**. Another small aperture is situated at the hind end. This is the excretory pore. There is no anus. The entire body is covered with thick tough cuticle which is produced into numerous tiny backwardly-directed spines.

(*iv*) **Life-history** (Fig. 30.3). The worm is **hermaphrodite or bisexual**, *i.e.*, it has organs of both the sexes. There, however, occurs cross-fertilization, which involves pairing of two worms. The fertilized egg, along with a mass of yolk cells, gets enclosed in a chitinous shell. The structure, thus formed, is termed the **capsule**. One worm may produce about 500,000 capsules. The capsules pass out through the genital pore into the bile-ducts of the host. From here, they are carried by the bile into the alimentary canal of the host. They finally leave the host with the faeces. If they fall in water or on damp soil, their development, which has already start.d in the worm, is completed. A tiny conical ciliated larva, the **miracidium**, hatches from each capsule. The miracidium swims in water or moisture film with its cilia. It soon enters the body of a fresh-water snail of the genera *Limnaea*, *Planorbis* or *Bulinus*. The snail serves as the **secondary host**. The miracidium dies if it fails to get a suitable snail within eight hours. Inside the snail, it loses cilia and metamorphoses into an immobile closed sac called the **sporocyst**. In the sporocyst another kind of larve, known as the **rediae**, are formed. The rediae break through the wall of the sporocyst. Each redia has in front a mouth leading into a short gut, a small birth-pore on one side and a pair of lateral flaps for locomotion near the hind end. It feeds on fluid and cells of the host's tissues and grows in size. The redia may form in itself a second generation of rediae or a new type of larvae

called the cercariae. The latter leave the redia through the birth-pore. **The** cercaria has an oval body bearing a slender tail. It has some

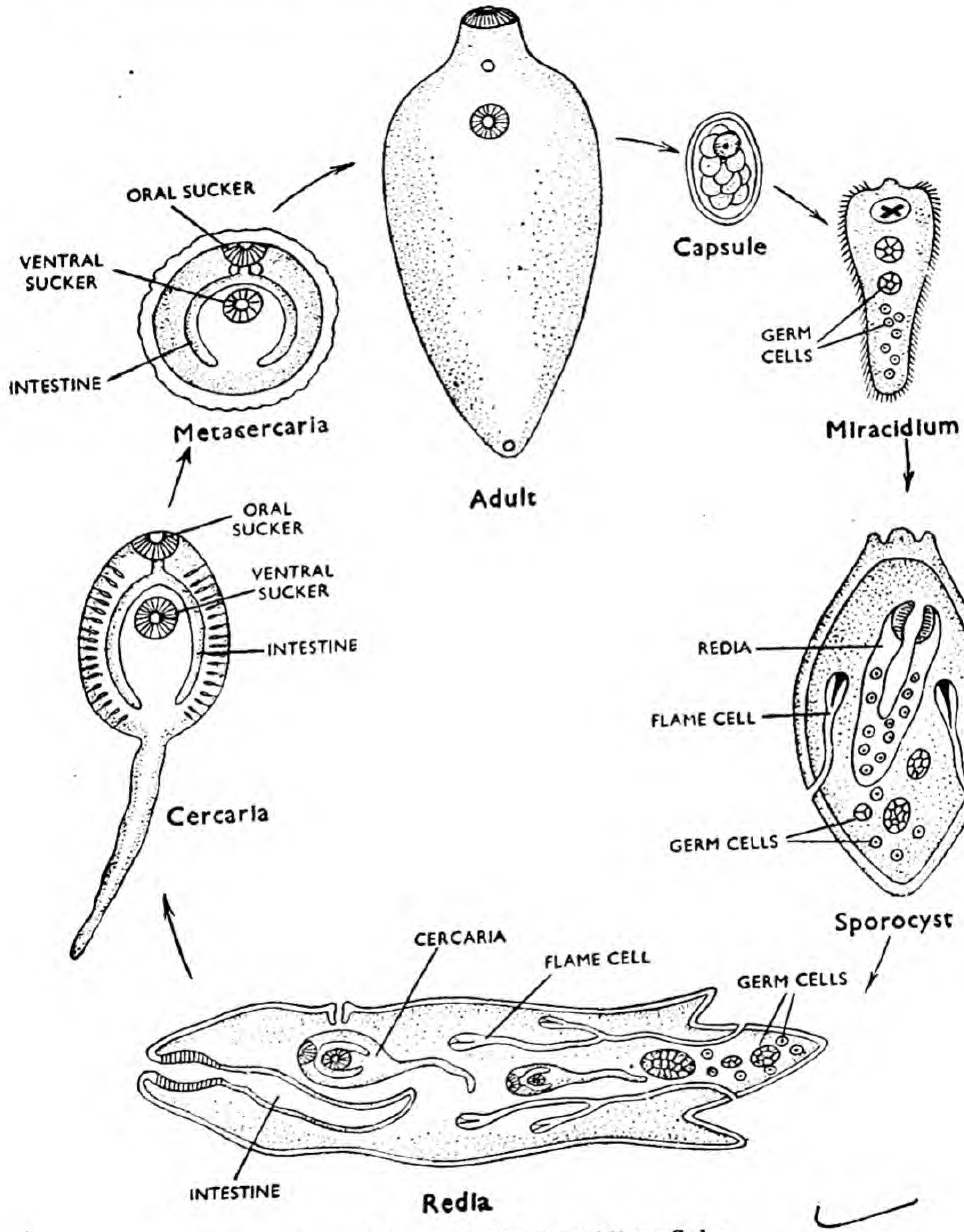


Fig. 30.3. Life-history of liver-fluke

features of the adult worm, *e.g*, oral and ventral suckers, forked gut and excretory pore. The cercaria leaves the snail and swims in water. From here, it may enter a sheep while it is taking water. In dry places,

the cercaria loses tail and becomes encysted on vegetation. The encysted cercaria is known as the **metacercaria**. The sheep and goats swallow metacercariae with food which consists of vegetation. The cysts break in the stomach and the cercariae are liberated. They bore their way through the wall of the stomach and enter the body-cavity. From here they penetrate the liver. For several weeks they damage the liver cells. Finally, they reach the bile-ducts and grow into adults.

Effect on the Host. The liver-fluke impairs liver metabolism by damaging its cells. It interferes with the digestion of food by blocking the bile-ducts. Its excretory matter has a poisoning effect. Heavy infections cause a disease called **"liver rot"**. It is characterised by erosion of the liver into a broken mass of tissue. The disease reduces the vitality of the host and may prove fatal.

(*v*) **Control Measures**. The snails are essential for the completion of the life-history of the liver-fluke. Destruction of snails is, thus, the most suitable measure to control the parasite. Snails thrive in wet pastures. Draining of pastures will, therefore, exterminate them. If this is not possible, it is profitable to introduce ducks and geese, which eat up the snails. The adult worms in the infected hosts can be killed with various drugs like **hexachloroethane.**

(*vi*) **Adaptations**. The liver-fluke has a few special features which help it in its parasitic life. These features are called adaptations. The suckers provide it with firm attachment in the bile-ducts. The backwardly directed spines erode the liver-cells which form its food and also save it from being washed down the ducts with bile. The cuticle protects it from the host's antitoxins. The production of enormous number of capsules and multiplication in the larval stages counteract wastage of capsules and larvae during transference from one host to another.

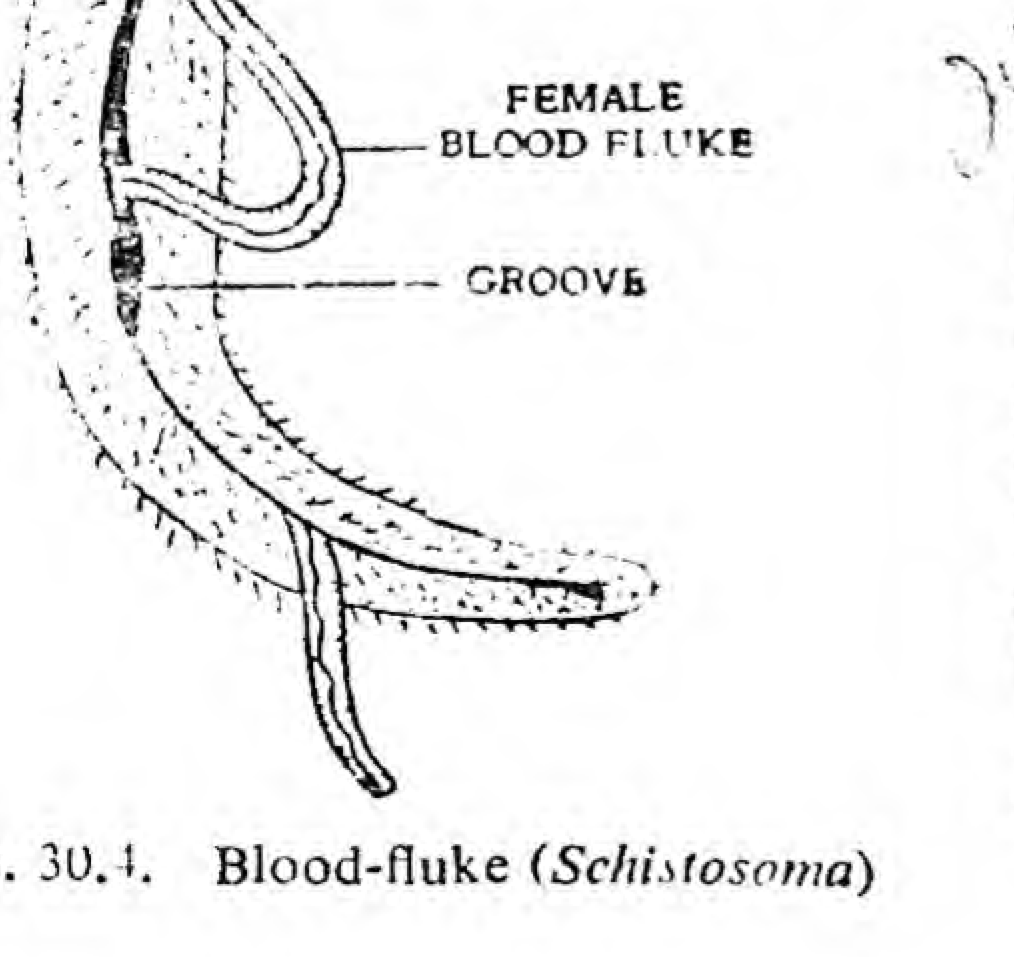


Fig. 30.4. Blood-fluke (*Schistosoma*)

2. Schistosoma. *Schistosoma* (Fig. 30.4) is commonly called the **blood-fluke**. Three species infect man. *S. haematobium* lives in the veins of the bladder in Egypt, Spain, Portugal and Near East. *S. mansoni* inhabits the mesenteric veins in Africa, West Indies and northern part of South America. *S. japonicum* occurs in the mesenteric veins in Eastern Asia, Formosa, Japan, Philippines and Singapore. The blood-fluke is

unisexual and cylindrical. The robust male carries the slender female in a special groove, the **gynecophoral canal**, formed by infolding of the margins of the body behind the acetabulum. Capsules are laid by the female in the capillaries which burst to release the capsules into the bladder or intestine. They pass out with urine or faeces and hatch in water. Snails serve as the intermediate host. The cercariae leave the snail and penetrate the human body through the skin during bath in rivers, canals, tanks, etc. Via circulation, they reach the liver, grow into adults and migrate to their final habitat.

The parasites damage the liver and cause intestinal disorders. Tartar emetic or sodium antimony tartarate are used for the treatment of schistosomiasis.

Class 3. Cestoda. The cestodes are commonly called the tapeworms. They are intestinal parasites of vertebrates. They have a long, narrow, ribbon-like body without pigmentation. It consists of a minute knob-like head or **scolex**, a short **neck** and a long **strobila** of a few to

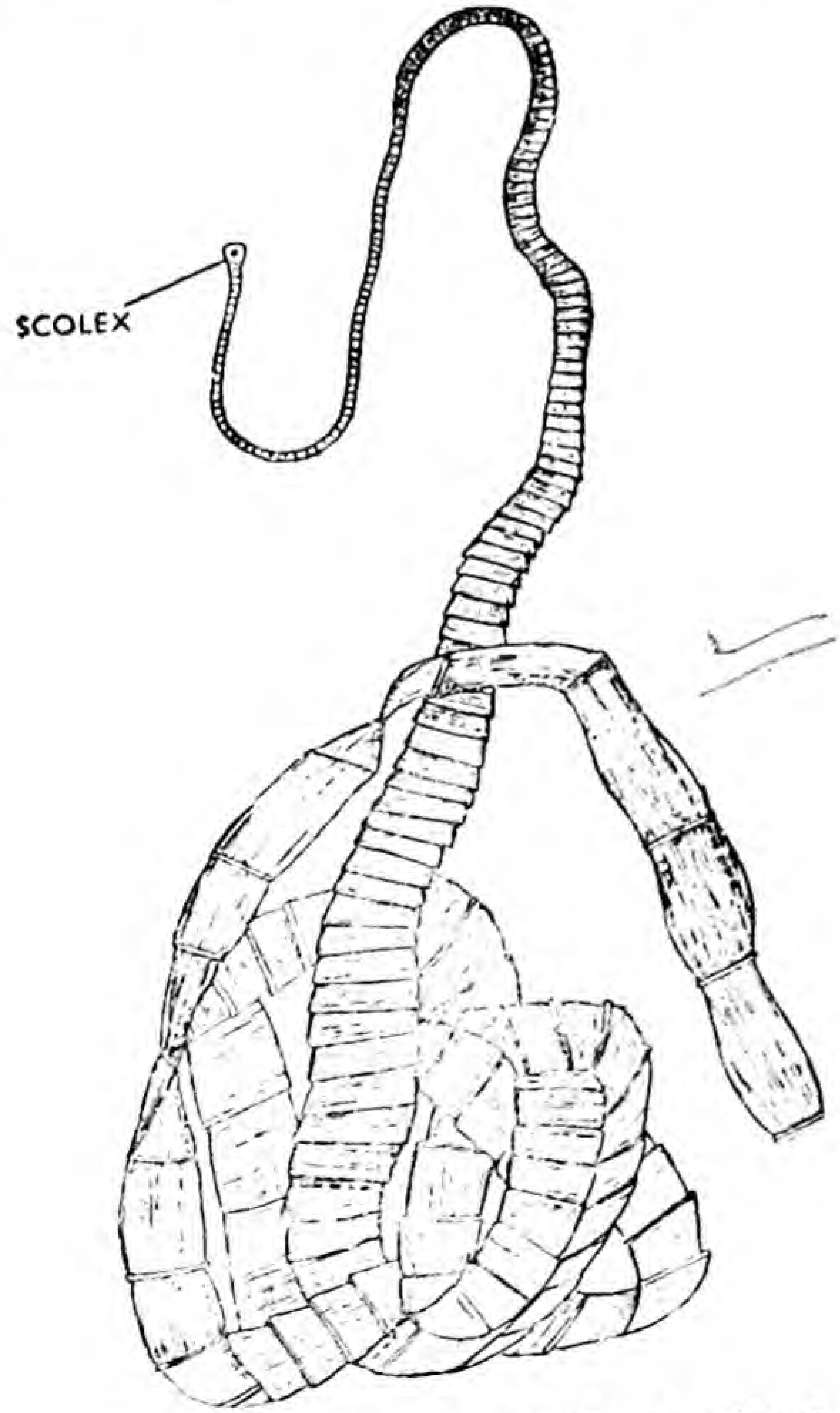


Fig. 30.5. Tape-worm (*Taenia solium*)

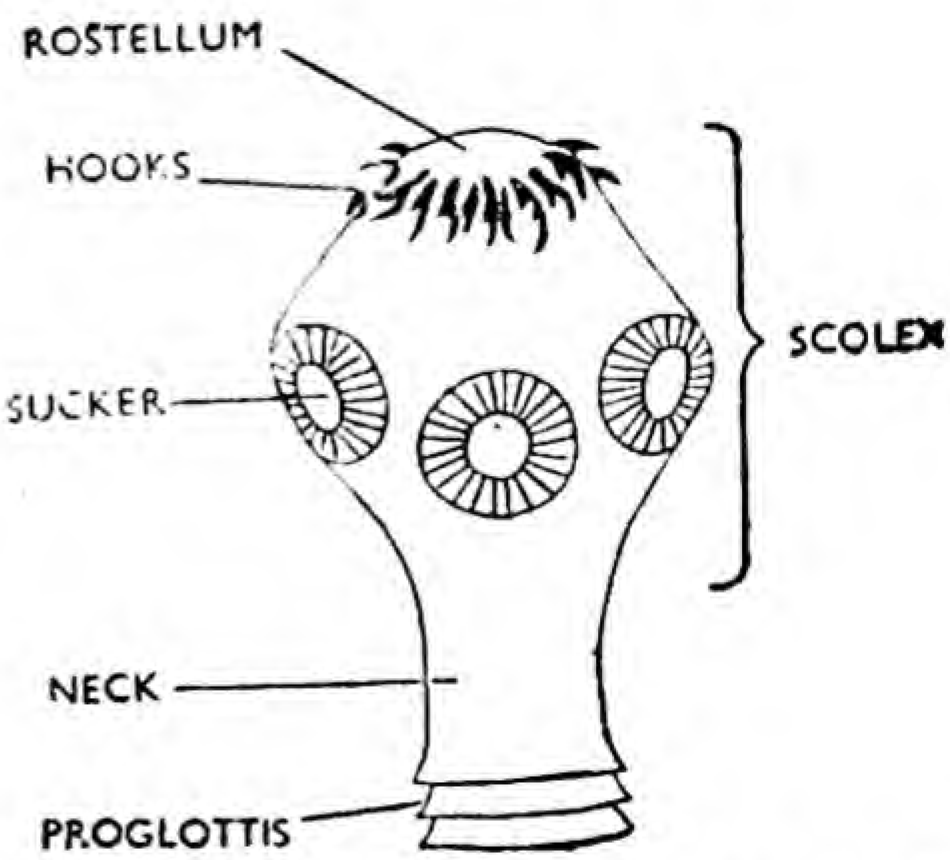


Fig. 30.6. Scolex of a tape-worm magnified.

several hundred segments or **proglottides.** The scolex (Fig. 30.6) bears **suckers** and **hooks** for attachment to the intestinal wall. The neck buds off new proglottides which push the older proglottides backwards. As they shift backwards, the proglottides grow in size, mature and finally break off. The tapeworms are without cilia. They have a covering of thick resistant cuticle The mouth and alimentary canal are absent. The digested food of the host is absorbed through the body-wall. The sense organs are lacking. The male and female reproductive organs are repeated in all proglottides. Larvae live in the tissues of some intermediate host. *Taenia* and *Echinococcus* are familiar examples.

1. **Tape-worm**. The common tape-worm of man is *Taenia solium*.

(*i*) **Habitat.** *Taenia solium* (Fig. 30.5) lives in the intestine of human beings. It lies firmly attached to its walls.

(*ii*) **Habits**. The tape-worm lacks mouth. It, therefore, absorbs the digested food of the host through its skin. This mode of feeding is called **saprozoic**. It respires anaerobically as free oxygen is not available in the intestinal contents. In anaerobic respiration glycogen breaks down into fatty acids and carbon dioxide. The worm has enormous power of reproduction.

(*iii*) **External Characters**. The tape-worm has a long, flat, white, ribbon-like body tapering anteriorly. It attains a length of three or four metres and a breadth of six millimetres. The body consists of three regions : a small knob-like **head or scolex,** a short narrow **neck** and a long **strobila** comprising about eight hundred **proglottides** in a mature worm. The scolex (Fig. 30.6) bears in front a small rounded protrusible projection called the **rostellum.** At the base of the rostellum is a double row of curved chitinous hooks. Behind the hooks, the scolex has four, large, hollow suckers. The hooks and suckers serve to attach the worm in the intestine. The neck buds off new proglottides at the rate of seven or eight per day. The new proglottides grow in size and become mature. Each proglottis has a complete set of male and female sex-organs. The proglottides of the hind end are packed with egg capsules and are said to be '**gravid**'. The gravid proglottides break off in groups of four or five.

(*iv*) **Life-history** (Fig. 30.7). Generally, there is self-fertilization as one host usually harbours a single worm. Eggs may be fertilized by the sperms of the same proglottis or one proglottis may receive sperms from another proglottis by folding up of the body. A fertilized egg becomes enclosed, along with a large yolk cell, in a thin chitinous shell. The structure, thus formed, is termed the capsule. The egg develops into a six-hooked embryo called the **hexacanth embryo**. The embryo with its protective covering is termed the **onchosphere** A single gravid proglottis may contain thirty to forty thousand onchospheres. The gravid proglottides full of onchospheres break off in groups of four or five. They come out passively with the faeces of the host. They soon disintegrate and release the onchospheres. The latter survive for a considerable period but do not develop further unless taken by a pig which

is the secondary host. In the gut of the pig, the shell is digested away and the hexacanth embryo is released. With its sharp hooks, the embryo pierces through the intestinal wall and enters the blood or lymph-vessels. In the vessels, it circulates round the body. Finally, it leaves the vessels and enters the voluntary muscles of the tongue and limbs. Here it casts off the hooks and changes into a fluid-filled sac known as the **bladder worm** or **cysticercus**. Wall of bladder invaginates on one side and produces an inverted scolex. Later, the scolex gets everted. The cysticercus is now fully formed. It lies passively in

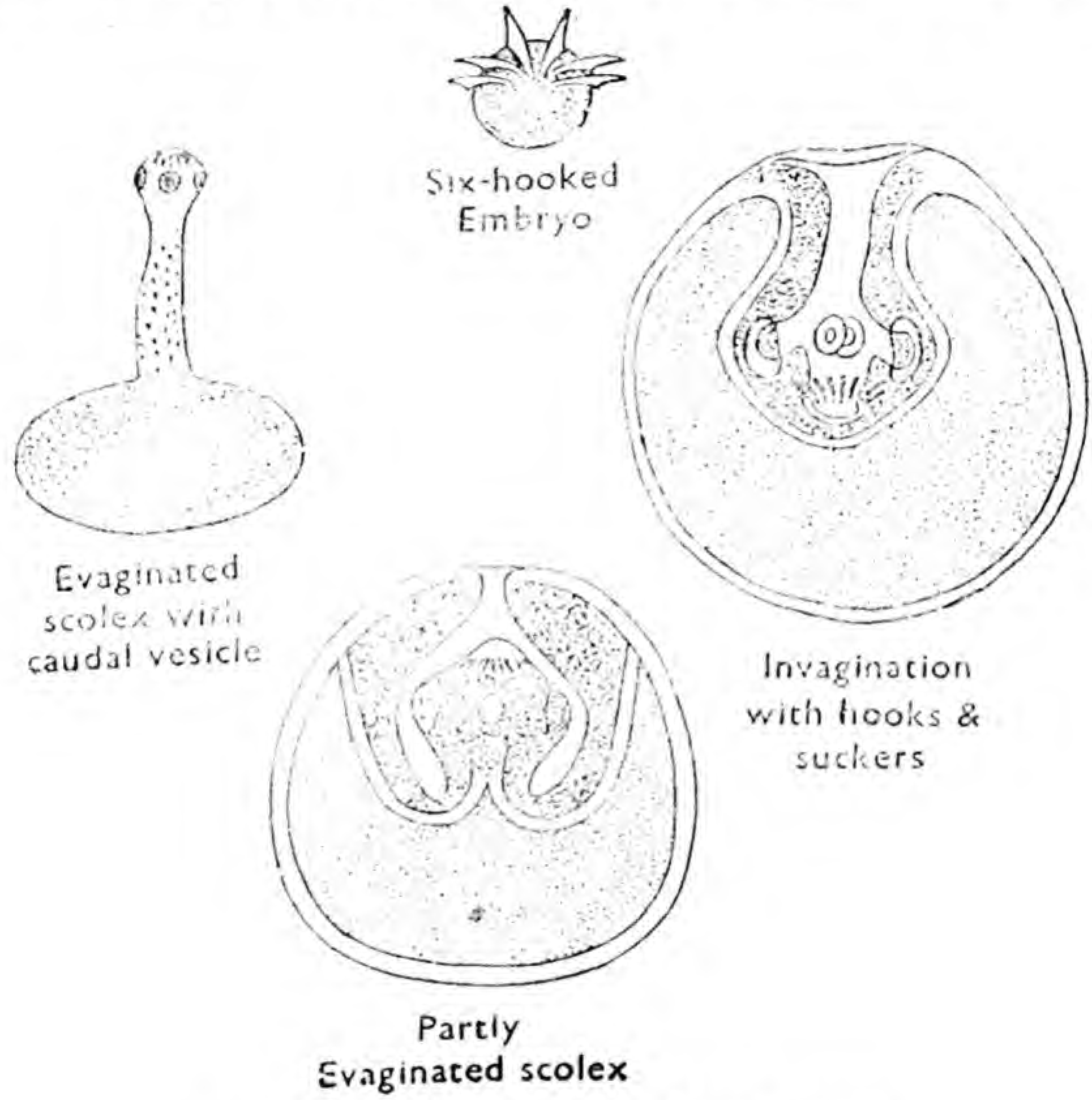


Fig. 30.7. Life history of tape-worm

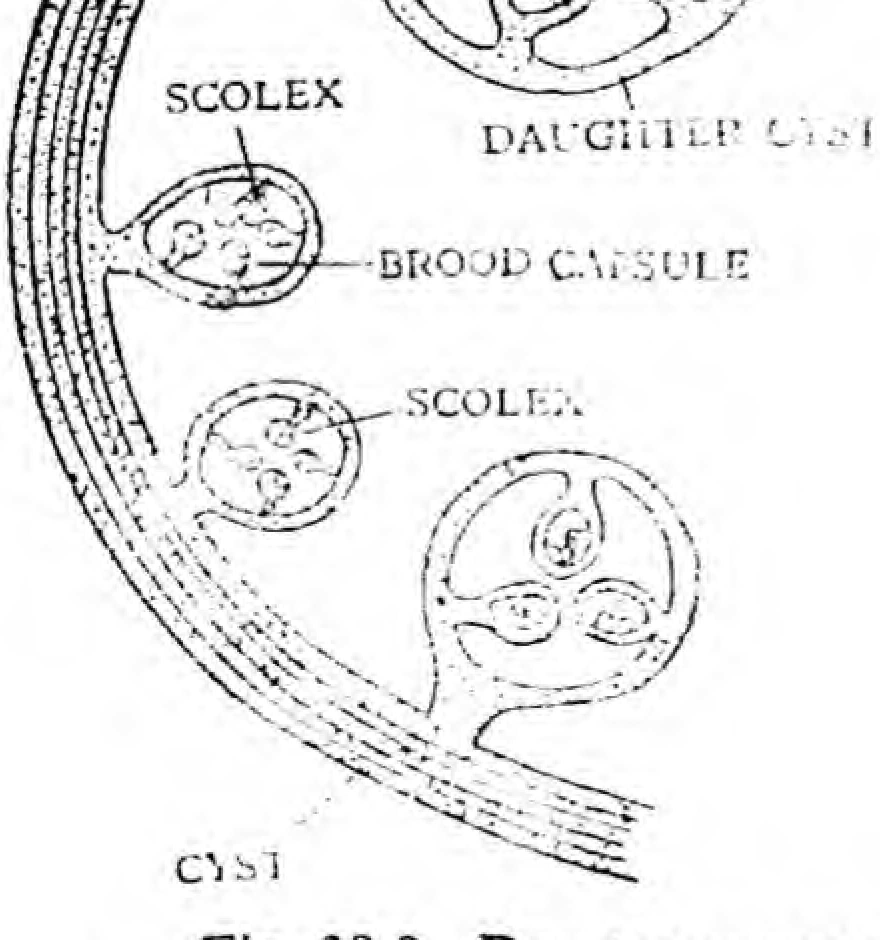
the muscles and awaits its entry into the primary host for further development. The infected pork has brown spots and is called the "**measly pork**". Infection of man occurs by taking raw or under-cooked measly pork. In the human intestine the bladder is cast off and the scolex attaches itself to the gut-wall. The neck starts budding off proglottides to form a tape worm. The worm becomes adult in two or three months.

(*v*) **Effect on the Host.** The tape-worm infection produces little effect on a person with sound health. Weak persons may develop a disease named **taeniasis**. This disease is characterized by abdominal pain, indigestion, vomiting, constipation, loss of appetite, lowered resistance to other diseases and nervous disorder.

(*vi*) **Control Measures.** Destruction of embryos, onchospheres and cysticerci, interferes with the life-history of the parasite and serves as an important measure to control its infection. The onchospheres may be destroyed through proper disposal of the human faeces by sewerage system or else by preventing the pigs from visiting human faeces. The cysticerci can be killed by thoroughly cooking the pork before eating it. Vermifuges like oil of male fern *Dryopteris* and oil of *Chenopodium* may be used to remove the adult worms from the human body. They, however, only remove the strobila and not the scolex. The latter can be removed only with a surgical operation.

(*vii*) **Adaptations.** The tape-worm shows a number of adaptations to its life in the alimentary canal. It has hooks and suckers for fixation. It can resist host's enzymes through some unknown mechanism. It respires anaerobically as free oxygen is not available in the intestinal contents. It has enormous power of reproduction to balance wastage of embryos during transference from man to pig and pig to man. It can survive more than thirty years and every year it sheds about 2,500 gravid proglottides, each containing 30,000 to 40,000 onchospheres. Loss of mouth and alimentary canal is co-related with the fact that the worm is permanently immersed in digested food, which can be easily absorbed through the skin.

2. **Echinococcus.** *Echinococcus granulosus* (*Taenia echinococcus*) is commonly called the **dog tape-worm or hydatid worm** (Fig. 30.8). It inhabits the intestine of dogs and other carnivores. It is only 3—6 mm. long. The scolex has 4 suckers and an armed rostellum. The strobila



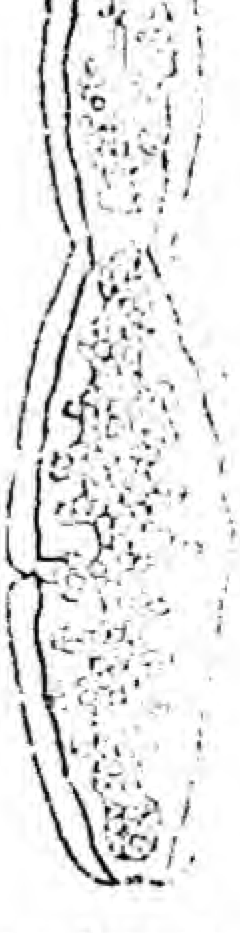


Fig. 30.8. Dog-tap worm (*Echinococcus granulosus*)
Left—A part of hydatid cyst, Right—A mature worm

consists of only 4 proglottides. Capsules pass out with host's faeces and contaminate vegetation and water. Herbivores like sheep and goats serve as intermediate hosts. They get infection by ingesting contaminated vegetation. The hexacanths bore through the gut wall and get lodged in the liver or lungs. They develop into peculiar fluid-filled bladders called the **hydatid cysts**. The wall of the cyst consists of an inner germinal layer called the **endocyst** and an outer cuticular layer termed the **ectocyst.** A fibrous layer, known as the **pericyst**, is secreted round the ectocyst by the host tissue.

The hydatid cysts multiply asexually by exogenous and endogenous budding. In exogenous budding, wall of the hydatid cyst bulges out and forms daughter cysts. In endogenous budding, the inner surface of the hydatid cyst buds off daughter cysts into its cavity. The internal daughter cysts are called the brood capsules as each buds off from its inner surface up to 30 scolices. Scolices may also arise directly from the germinal layer of the parent hydatid cyst. The brood capsules ultimately burst, setting the scolices free in the fluid filling the parent cyst. The dogs often take raw flesh of sheep and goats near mutton shops and thus swallow hydatid cysts packed with scolices. Each scolex grows into a tape-worm in dog's intestine.

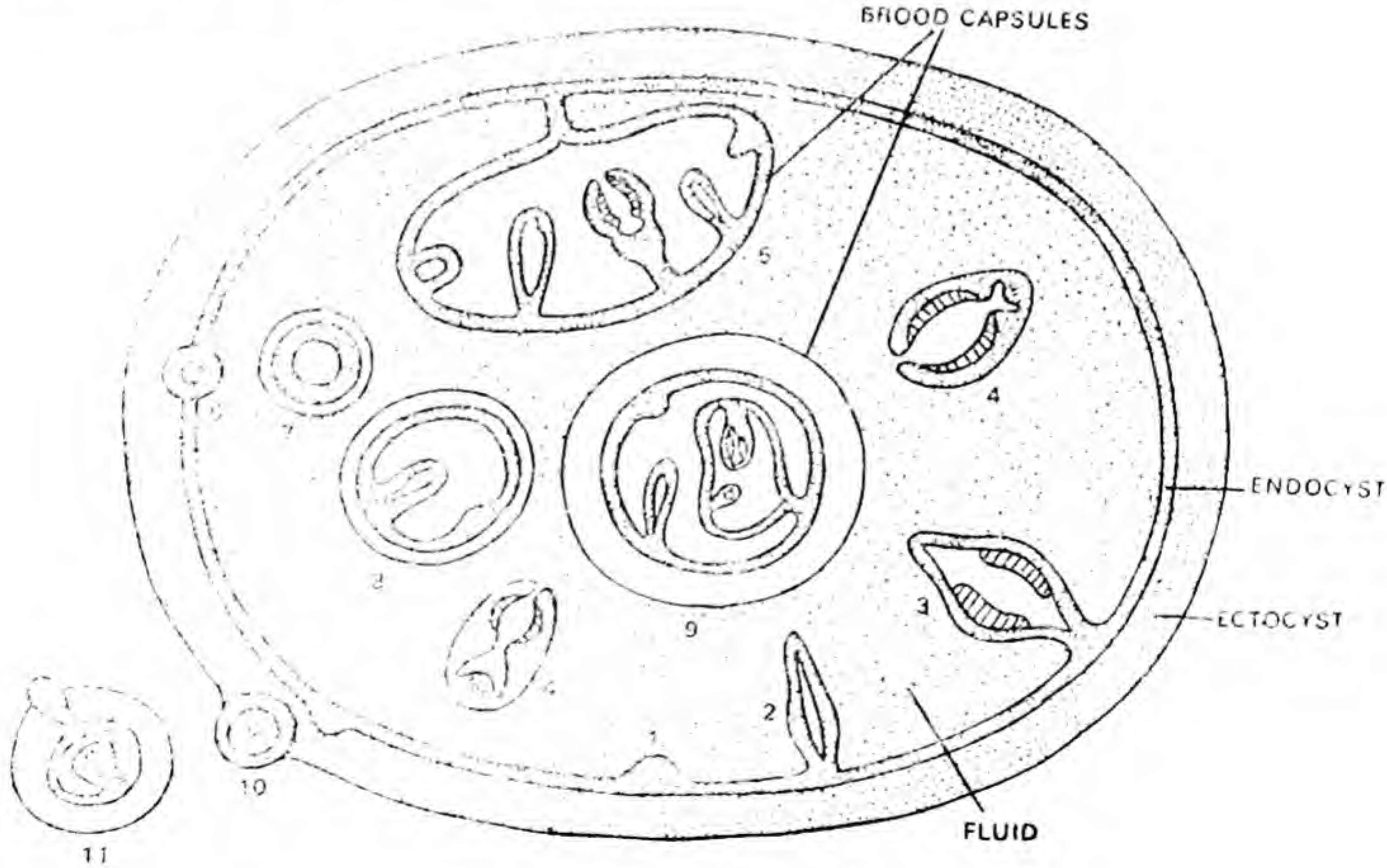


Fig. 30.9. Hydatid cyst

Man is an incidental intermediate host of the dog tapeworm. Human infection occurs from the pet dogs. Some capsules remain sticking to the anal region of the dog after defaecation. From here, they are licked up by the dog and deposited on its fur. From the fur they reach the

human hands and finally the mouth. Too much intimacy with dogs should, therefore, be avoided.

IV. Economic Importance

The free-living flat worms have little economic value. The parasitic forms are very harmful. Some of them directly affect man's health and existence by parasitizing his body. Many indirectly affect man's economy by living in and harming the useful animals like cattle, pigs, sheep and goats.

V. Summary

Phylum **Platyhelminthes** (plat-ee-hel-min-theez) : Flat-worms.

Class 1. **Turbellaria** (tur-be-lair-ee-a) : Free-living, *e.g. Dugesia.*

Class 2. **Trematoda** (trem-a-to-da) : Parasitic, *e.g.* liver-fluke, blood-fluke.

Class 3. **Cestoda** (ses-to-da) : Parasitic, with detachable proglottides, *e.g.* tape-worm, hydatid worm.

TEST QUESTIONS

1. Give the characteristics of phylum Platyhelminthes. Name and describe its classes.
2. Write an ecological note on the following animals and give their taxonomic position :—

   Dugesia, Liver fluke, Tapeworm.
3. Give an illustrated account of the form and life-history of the liver-fluke.
4. Discuss the effects of liver-fluke and tape worm on their hosts. What measures would you suggest to control these worms ?
5. Describe the life-history of the tape-worm. How does this worm differ from the liver-fluke as regards the external characters ?
6. Discuss the features which help the tape worm in its parasitic mode of life.

CHAPTER 31

Phylum Aschelminthes

(The Bag-worms)

I. Characteristics

The phylum Aschelminthes includes the roundworms and allied animals. These animals show the following characters :—

1. The bag-worms have bilateral symmetry.
2. They are triploblastic and unsegmented animals.
3. They possess an elongated, flattened or cylindrical body.
4. The body lacks suckers. It is covered with a smooth, tough, resistant cuticle.
5. The body-wall contains longitudinal muscles only.
6. The body-cavity is present but it is not lined by an epithelium and is called the **pseudocoel.**
7. The digestive tract is complete and straight with a terminal mouth and a sub-terminal anus.
8. The respiratory, circulatory, and skeletal systems are undeveloped.
9. The nervous system includes a nerve-ring round the anterior part of the alimentary canal and longitudinal nerve-cords.
10. The excretory system has one or two longitudinal excretory ducts opening out at the excretory pore.
11. The bag worms are usually unisexual and show a distinct sexual dimorphism, the males being smaller than the females. The gonads have ducts.
12. The development is direct.
13. There is no asexual reproduction.
14. They are free-living as well as parasitic.

II. Advancement

The Aschelminthes show advancement over Platyhelminthes in having

(*i*) a body-cavity,

(*ii*) unbranched and camplete digestive tract and,

(*iii*) separate sexes.

III. Classification

The phylum Aschelminthes includes six classes. Only one, namely,

Nematoda, will be discussed here. The nematodes are popularly called the round worms. They have a cylindrical non-ciliated body, tapering at one or hoth the ends. *Ascaris lumbricoides* variety *humanis* is a familiar example of round worms.

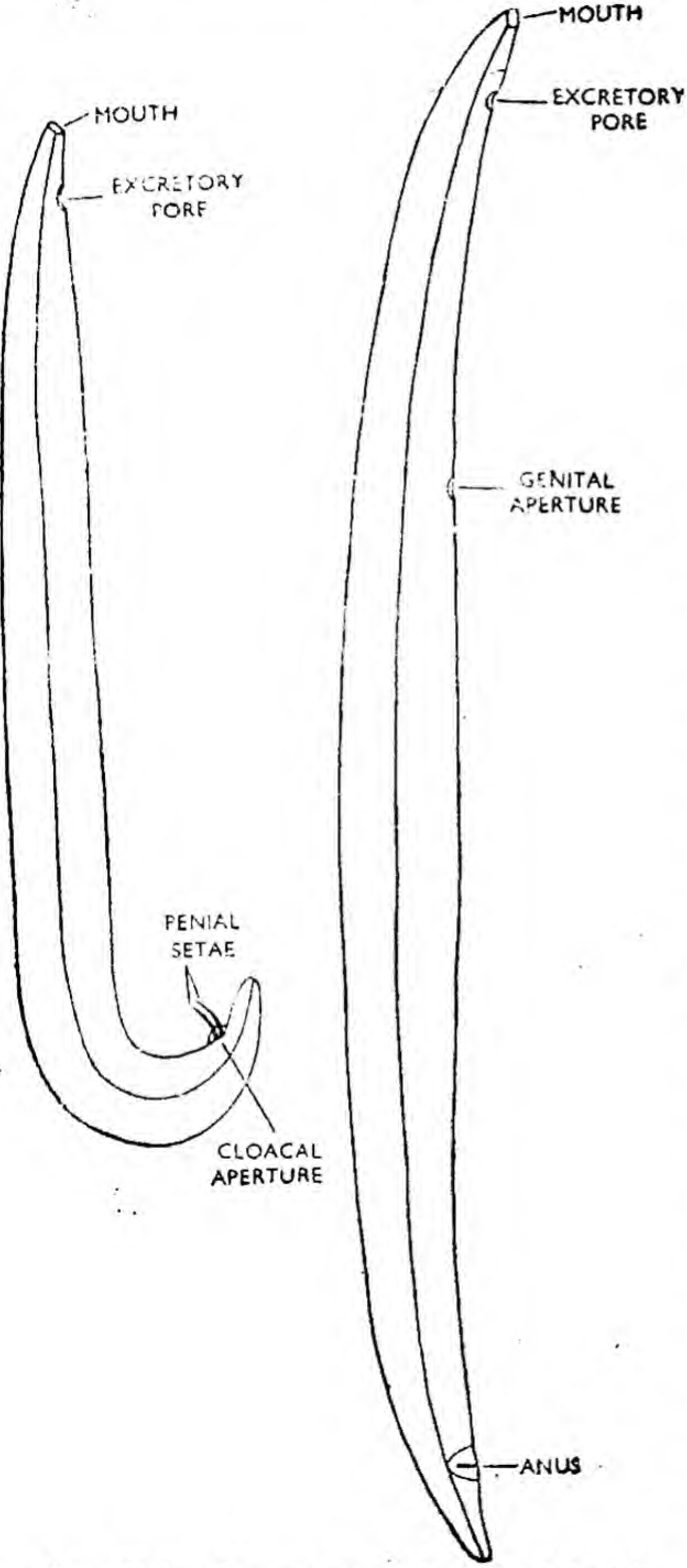


Fig. 31.1 *Ascaris*—male (left) and female

Ascaris lumbricoides. *Ascaris lumbricoides* (Fig. 31.1) is a parasitic roundworm.

(*i*) **Habitat**. *Ascaris lumbricoides* lives in the small intestine of man. It lies freely in the cavity of the intestine.

(*ii*) **Habits.** *Ascaris* feeds on fluids present in the intestinal contents of the host. Ingestion occurs by sucking action. The worm respires by the break-down of glycogen into fatty acids and carbon dioxide in its body as free oxygen is not available in the intestinal contents of the host. It moves by dorso-ventral twistings of the body. There is evidence to show that *Ascaris* produces an antienzyme to counteract the host's enzymes. Its thick cuticle also provides some protection to it from the host's digestive juices.

(*iii*) **External Characters.** The sexes are separate. The female is larger and measures 20 to 40 centimetres in length and 6 millimetres in diameter. The male is smaller and has a sharply-curved posterior end. It measures 15 to 30 centimetres only. Both the sexes have a cylindrical body, which tapers at either end. The body is marked with four **longitudinal streaks** : one dorsal, one ventral and two lateral. The **mouth lies** at the anterior end surrounded by three **lips,** one dorsal and two ventro-lateral. A little in front of the hind end, there

lies the **anus** on the ventral side. In the male, the anus also serves as the genital **aperture** and may be called the **cloacal aperture**. Two minute chitinous rods project through the cloacal aperture. These are called the **penial spicules**. The female has a separate genital aperture or **vulva**. It is situated midventrally at about one-third of the body from the front end. Both the sexes have an **excretory pore**, a little behind the anterior end on the ventral side.

(*iv*) **Life-history**. Fertilization is internal. The female lays eggs in the host's intestine. The eggs are enclosed in chitinous shells and are produced in enormous numbers. A single worm may contain as many as 27 million eggs in various stages of development at one time and they are laid at the rate of 15,000 to 200,000 per day. The eggs pass out with the faeces of the host. They are very resistant and can remain alive on the soil for several months. Embryos are formed in the eggs in about fourteen days under favourable conditions.

The healthy persons get infection of *Ascaris* by swallowing its eggs containing embryos. These eggs reach the mouth with food, water and soiled hands. The eggs pass from the stomach into the small intestine. Here, they hatch into **larvae** or **juveniles** within a few hours. The larvae bore through the wall of the small intestine and enter the veins and lymph-vessels. Those entering the veins pass through the liver and reach the heart. Those entering the lymph-vessels pass into the blood and reach the heart directly. From the heart they are carried by the blood to the lungs. From the blood-vessels of the lungs they enter the cavities or air-sacs of the lungs. Now they move through the trachea, throat, oesophagus and stomach to the small intestine again. This journey in the host is completed by the worm in about ten days. In the intestine the worm grows and becomes mature in about 2½ months.

(*v*) **Effect on the Host**. *Ascaris* generally does not harm the host. Sometimes, however, it may cause diarrhoea, bronchitis and even pneumonia. When in large numbers, the worms obstruct the intestine and prove fatal.

(*vi*) **Control Measures**. Disposal of human faeces by underground sewerage system is an efficient measure to control *Ascaris* infection. Thoroughly washing the vegetables and fruits before eating is very helpful in preventing the access of the eggs to the mouth. Adult worms are removed from the intestine by using drugs like **santonin** and **thymol**.

IV. Economic Importance

The Aschelminthes are very harmful. Many of them like the pin-worm, hook-worm, filarial worm, trichina worm and guinea-worm are human parasites. The round worms also attack the domestic animals, *e.g.* horse, sheep, pig, dog and chicken. The round-worms do not spare even the plants. Some of the very useful crops and fruit trees like potatoes, wheat, sugar beet, citrus, etc. suffer from the round-worm diseases. Some free-living round-worms pollute drinking water of wells and reservoirs.

TEST QUESTIONS

1. Name the phylum of the round worms and give its important characters.
2. Write a short ecological note on *Ascaris*.

CHAPTER 32

Phylum Annelida

(The Segmented Worms)

I. Characteristics

The phylum Annelida includes the sand worms, earthworms and leeches. The annelids show the following characters :—

1. They have bilateral symmetry.
2. They are triploblastic.
3. The body is elongated, cylindrical or flattened and conspicuously segmented, both externally and internally.
4. The body may have head and unjointed appendages, the parapodia.
5. The body-cavity is a **true coelom** lined by mesoderm. It is spacious in some, reduced in others.
6. The digestive tract is **complete** and straight extending along the entire body.
7. Respiration occurs by skin or gills.
8. Excretion is brought about by minute coiled tubes, the **nephridia**.
9. There is a closed circulatory system comprising **heart**, vessels and red blood with dissolved haemoglobin and amoeboid corpuscles.
10. The nervous system consists of a pair of dorsal cerebral ganglia forming the brain, a pair of connectives round the anterior part of alimentary canal and a ventral, solid, ganglionated nerve-cord.
11. The sexes may be united or separate.
12. Development occurs with or without a larval stage.
13. Some forms show asexual reproduction.
14. The annelids are found all over the world in the sea, in fresh water and in the moist soil.

II. Advancement

The Annelida show advancement over the Aschelminthes in having—

1. metameric segmentation,
2. head,
3. appendages,
4. true coelom,
5. nephridia for excretion,
6. distinct circulatory system,

7. circular and longitudinal muscles both in the body-wall and gut and
8. sense organs.

III. Classification

The phylum Annelida has three classes : **Polychaeta, Oligochaeta** and **Hirudinea.**

Class 1. Polychaeta—In Polychaeta, the anterior end of the body is specialised into a head which bears eyes and tentacles. The body bears lateral appendages, the parapodia, which bear numerous setae. Clitell-

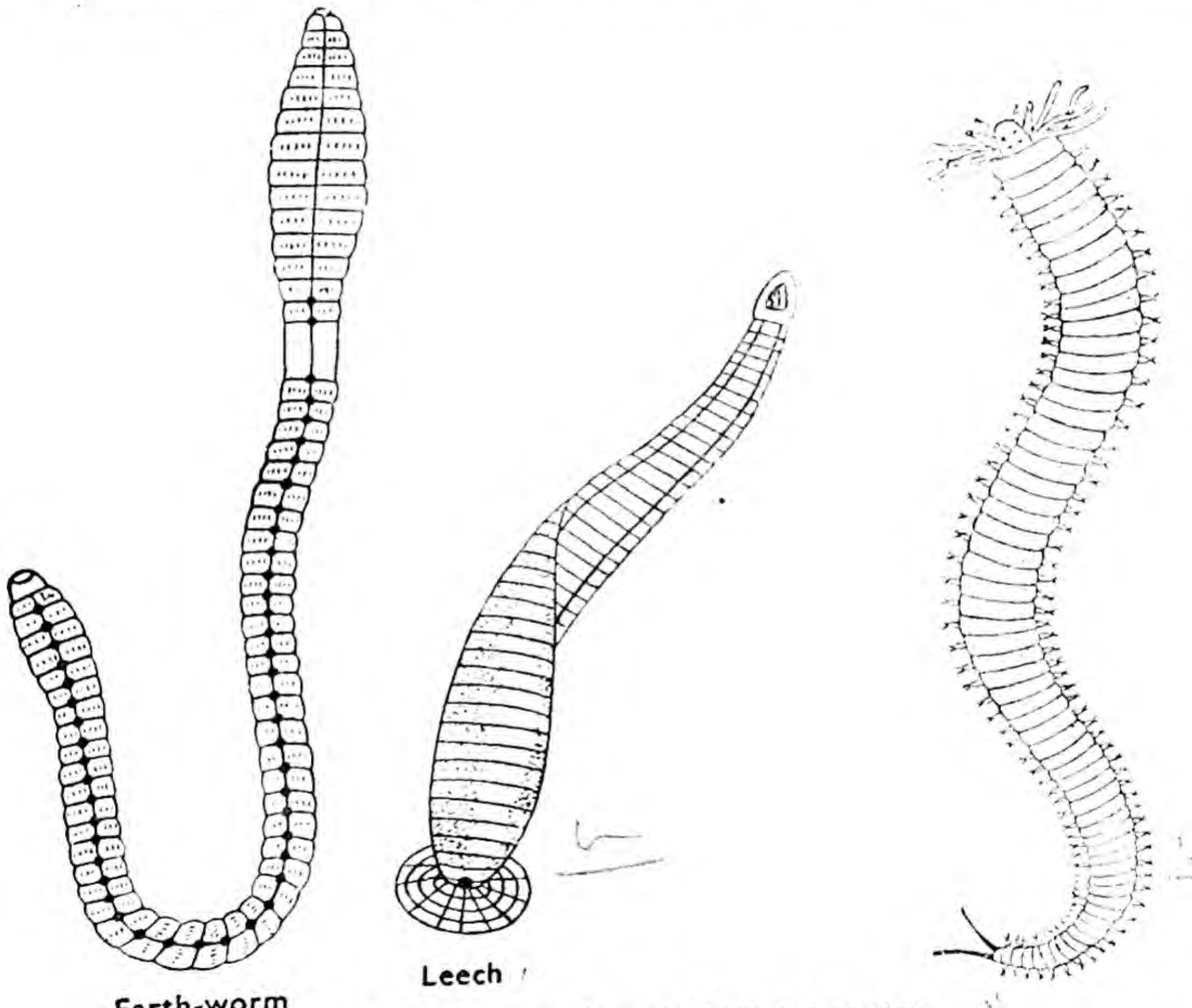


Fig. 32.1. Representatives of phylum Annelida

um is lacking. The sexes are separate and the development is with a larval stage. A few forms show asexual reproduction. Practically all the Polychaeta are marine. Sand or clamworm and the sea-mouse are the common representative.

Sand or Clamworm. The sandworm or clamworm, called *Nereis*, (Fig. 32.1) lives in the shallow coastal waters of all the seas. It may crawl on sand or swim in water. It is gregarious, nocturnal and omnivorous. During copulation the bodies of the worms burst to release the

sperms and eggs. The worms then usually die. Fertilization occurs in water.

The worm has a long, flattened, segmented body, with a distinct head bearing a pair of palps, five pairs of tentacles and two pairs of eyes. Each segment, except the first and the last, has a pair of parapodia for locomotion.

Sea-mouse. The sea-mouse (Fig. 32.2) is called *Aphrodite*. It is found below low water mark creeping over, or burrowing just beneath

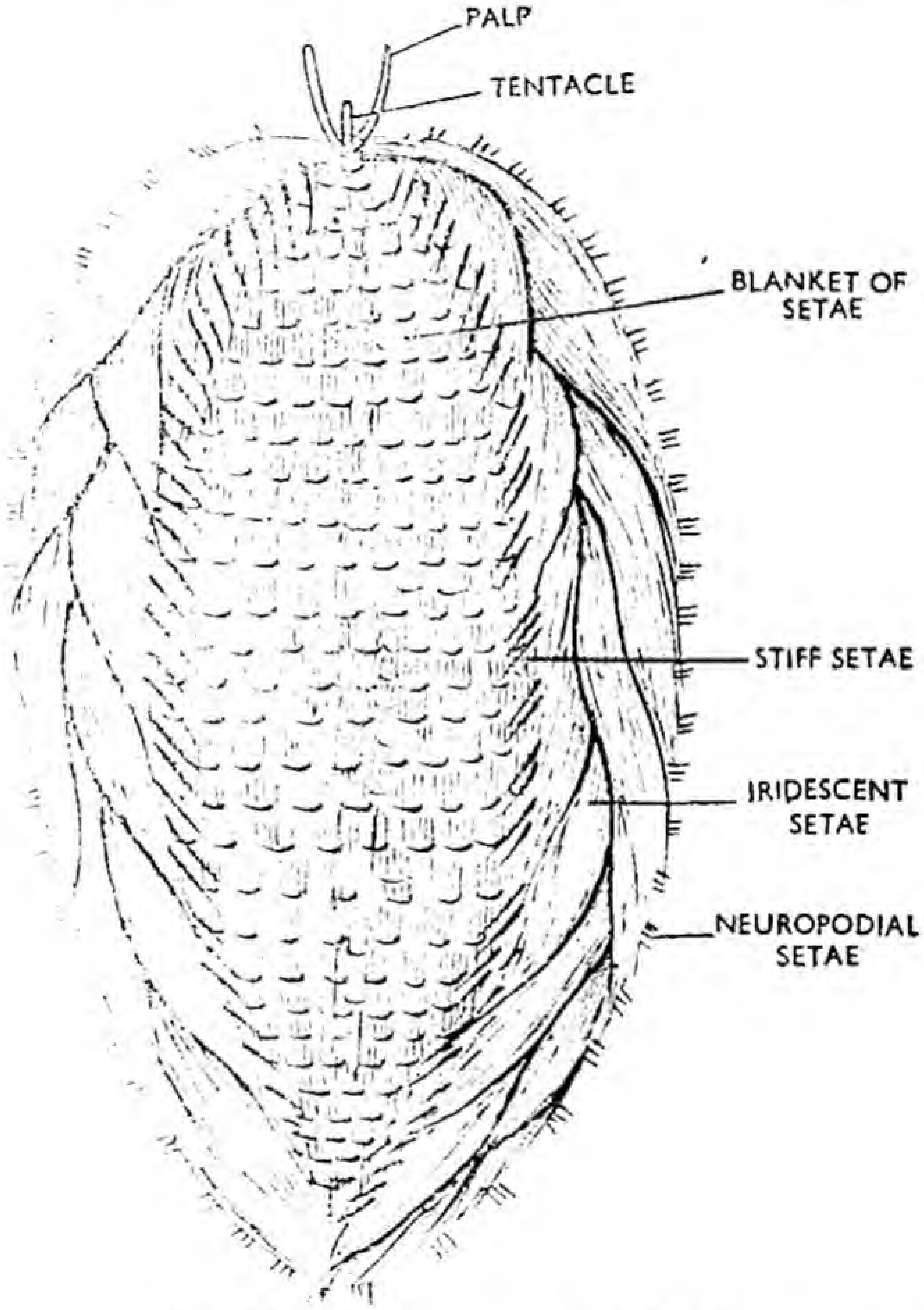


Fig. 32.2. Sea-mouse (*Aphrodite*)

the surface of sand. It has an oval body with convex dorsal and flat ventral surface. The prostomium and peristomium form a small head. The prostomium bears a pair of eyes, a short median tentacle and a pair of long palps. The anus lies on the dorsal surface of the more pointed posterior end. The dorsal parts of certain parapodia are modified into large flat scales, called **elytra**, that lie over the back. The elytra alternate with normal parapodia, but being very large, cover the back completely. The setae in the upper parts of parapodia are of three types : (*i*) long thread-like directed upwards and woven into a **blanket** over the elytra, (*ii*) stiff spine-like and (*iii*) iridescent bristle-like. The setae of the lower parts of parapodia are stiff and laterally directed.

Protrusible proboscis is present. The worm produces an irrigation current over the back by movement of the elytra and back itself. The current enters between the parapodia into a space between the body-wall and the elytra and leaves near the posterior end which is held up to the surface of sand. This current facilitates respiration through the elytra.

Class 2. Oligochaeta. The Oligochaeta have fewer setae. They lack head and parapodia. The clitellum is present. The sexes are united and development is direct. The oligochaetes live in fresh water and moist soil. The earthworm is the familiar example.

Earthworm. The earthworm (Fig. 11.1) is described in detail in chapter 11.

Class 3. Hirudinea. The Hirudinea have a flattened body with fewer segments. Each segment is subdivided externally by superficial annuli so that the external segmentation does not correspond with the internal one. There are no parapodia and setae. Instead, there are two suckers, one at each end of the body, for locomotion. The coelom is reduced being filled with connective tissue and muscles. The sexes are united and the development is direct. The class includes the leeches.

Leech. The Indian cattle leech (*Hirudinaria*) inhabits fresh water (Fig 32.1). It has a long, flat, brightly-coloured body with 33 segments. Each segment is subdivided externally by superficial annuli. There is a sucker at each end. There are no parapodia. The leech moves by looping action of the body on the solid objects using suckers for attachment. It also swims in water by graceful undulations of the body.

It sucks blood of cattle. It can store blood in its distensible crop enough for several months. A salivary enzyme, **hirudin**, prevents the clotting of blood in the crop.

IV. Economic Importance

Annelids are of considerable value to man. The role of earthworms in human economy has been already discussed. The leeches are largely used as fish bait. They are of some nuisance to the bathers and cattle. The medicinal leech is employed for "blood-letting" from septic wounds.

V. Summary

Phylum **Annelida** (an-nel-i-da) : Segmented worms.

Class 1. **Polychaeta** (pole-ee-kee-ta) : With parapodia, numerous setae, marine, *e.g Nereis, Aphrodite*.

Class 2. **Oligochaeta** (o-li-go-kee-ta) : No parapodia, fewer setae, fresh-water or terrestrial, *e.g*. Earthworm.

Class 3. **Hirudinea** (hir-oo-di-nee-a) : No setae or parapodia, parasitic, *e.g. Hirudinaria granulosa*.

TEST QUESTIONS

1 Discuss the distinguishing characters of the phylum Annelida. Give a brief classification of the phylum. Mention at least one example of each group.

2. Write a brief ecological note on leech and *Nereis*. Also classify them.

CHAPTER 33

Phylum Arthropoda

(The Joint-footed Animals)

I. Characteristics

The plylum Arthropoda includes water-fleas, crabs, prawns, centipedes, millipedes, insects, scorpions and spiders. These animals possess the following characters :—

1. They have bilateral symmetry.
2. They are triploblastic.
3. The body is variously-shaped and usually segmented externally.
4. The body has a distinct head with well-developed **sense organs.** It bears paired jointed appendages modified for the individual needs.
5. The cilia are absent.
6. There is a hard organic exoskeleton of chitin secreted by the underlying epidermis. The exoskeleton protects the internal organs and provides space for the attachment of muscles. It is moulted or cast off many times during growth.
7. The body muscles are striated and are arranged in separate bundles for moving particular joints.
8. The true coelom is greatly reduced in the adult, being represented only by the cavities of the excretory and reproductive organs. The body-cavity surrounding the internal organs contains blood and is called the **haemocoel.**
9. The digestive system is **complete**. The mouth is surrounded by appendages, called **mouth-parts**, which help in feeding.
10. Respiration occurs either through the body surface or by special structures like gills, tracheae and book-lungs.
11. The circulatory system has a dorsal pulsatile heart and is of the **open type**, *i.e.* blood does not flow in closed tubes but fills the body-cavity or haemocoel.
12. Excretion is brought about either by the green glands opening to the exterior or Malpighian tubules opening into the gut.
13. The nervous system, like that of the annelids, consists of a dorsal brain and a double, solid, mid-ventral, ganglionated nerve-cord.

14. The sexes are usually separate and often there is sexual dimorphism. The gonads have ducts.

15. The development includes a larval form.

16. The arthropoda are found everywhere—on land, in the soil, in fresh water, in sea-water and in the bodies of animals as well as plants. Some are gregarious and a few colonial with social life.

II. Advancement

The Arthropoda show advancement over Annelida in having—

(*i*) a distinct head,

(*ii*) jointed appendages,

(*iii*) no cilia,

(*iv*) chitinous exoskeleton,

(*v*) bundles of striated muscles for moving particular parts,

(*vi*) well developed sense organs like compound eyes, statocysts and tactile bristles,

(*vii*) special respiratory organs like gills, tracheae and book-lungs, and

(*viii*) separate sexes.

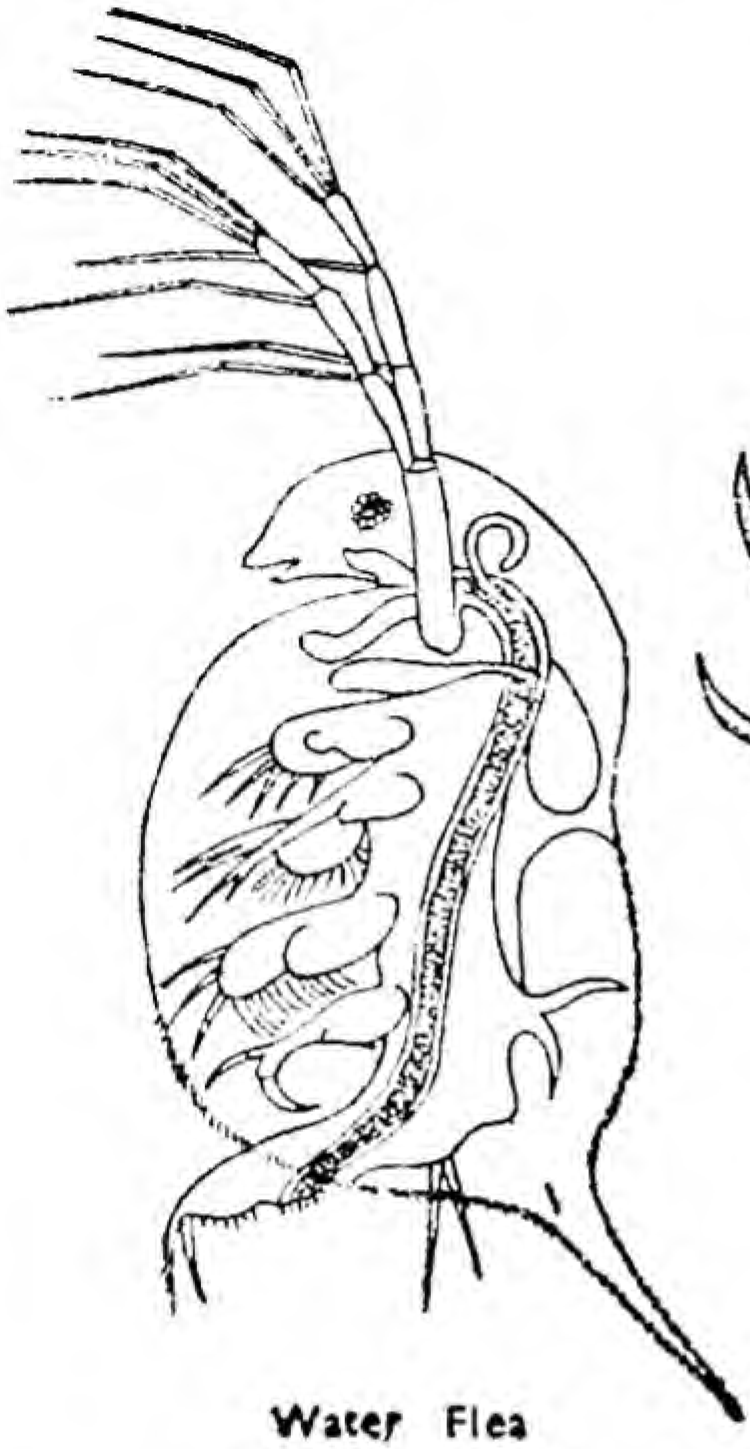
III. Classification

Arthropoda is the largest phylum as it includes about 80% of all the known species of animals. It is divided into five main classes: **Crustacea, Chilopoda, Diplopoda, Insecta and Arachnida**

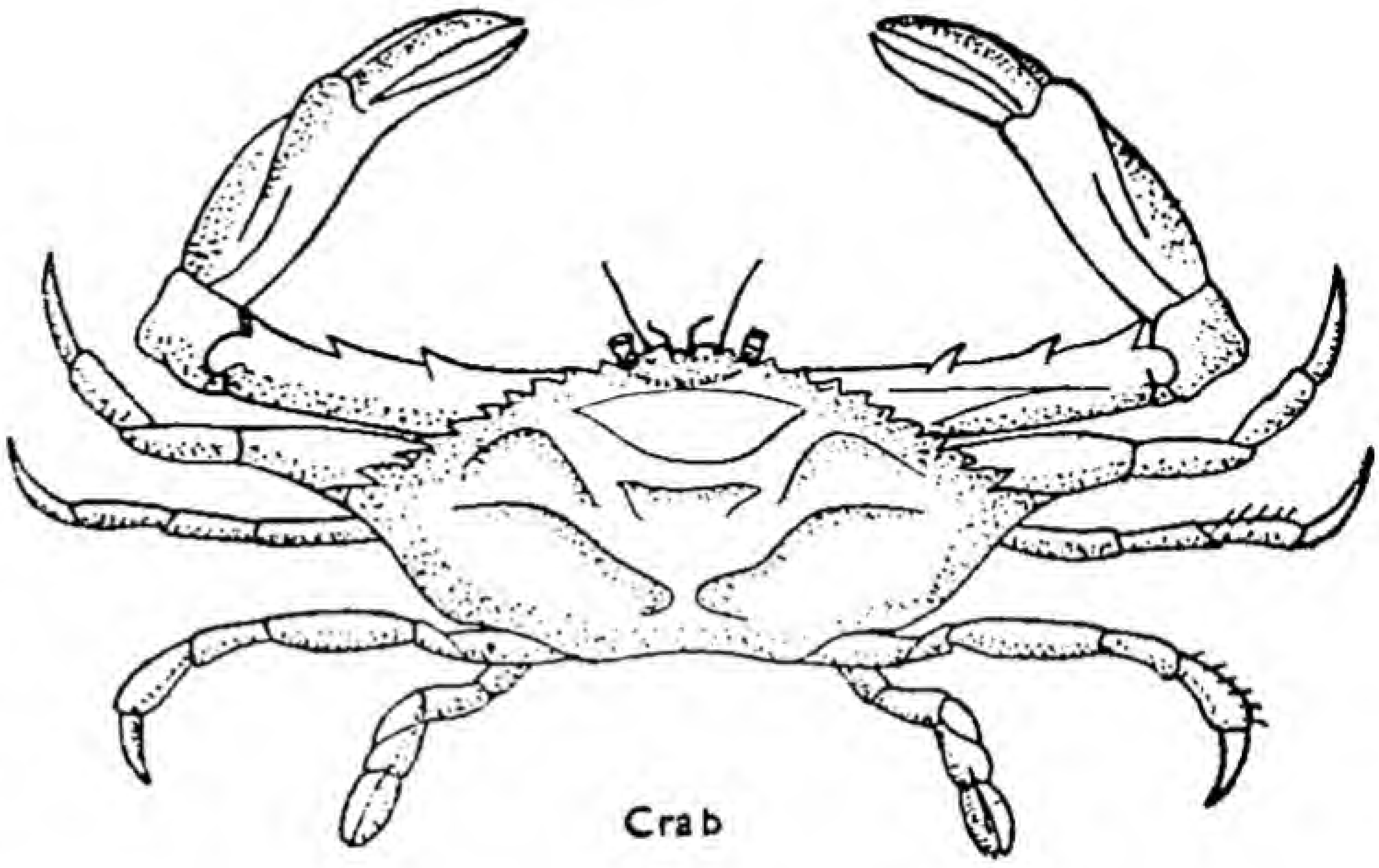
Class 1. Crustacea. The thick chitinous exoskeleton is generally strengthened by impregnation with calcium salts. The body is divisible into three regions : *head, thorax* and *abdomen.* The head is often fused with a part or whole of the thorax to form the **cephalothorax**. The head bears a pair of compound eyes, two pairs of antennae, a pair of mandibles and two pairs of maxillae. The thorax and abdomen bear one pair of appendages on each segment. All the appendages, except the first pair of antennae, are biramous, *i.e.* each consists of a basal part or protopodite which bears two branches : the inner endopodite and the outer exopodite. Respiration usually occurs by gills. Excretion takes place by one or two pairs of green glands which open to the exterior. There is usually metamorphosis in the life-history. The crustaceans are typically aquatic and are found both in sea and fresh water. Some live on land and a few are parasites. This class is represented by water-fleas, crabs and prawns.

Water-flea. The water-flea (Fig. 33.1 A) is a small fresh-water crustacean having a single eye. It has a laterally-compressed body enclosed in a bivalve shell or **carapace** which ends posteriorly in a prominent **caudal spine**. Large biramous antennae form the chief locomotory organs. The female has a brood pouch on the back for carrying eggs and embryos.

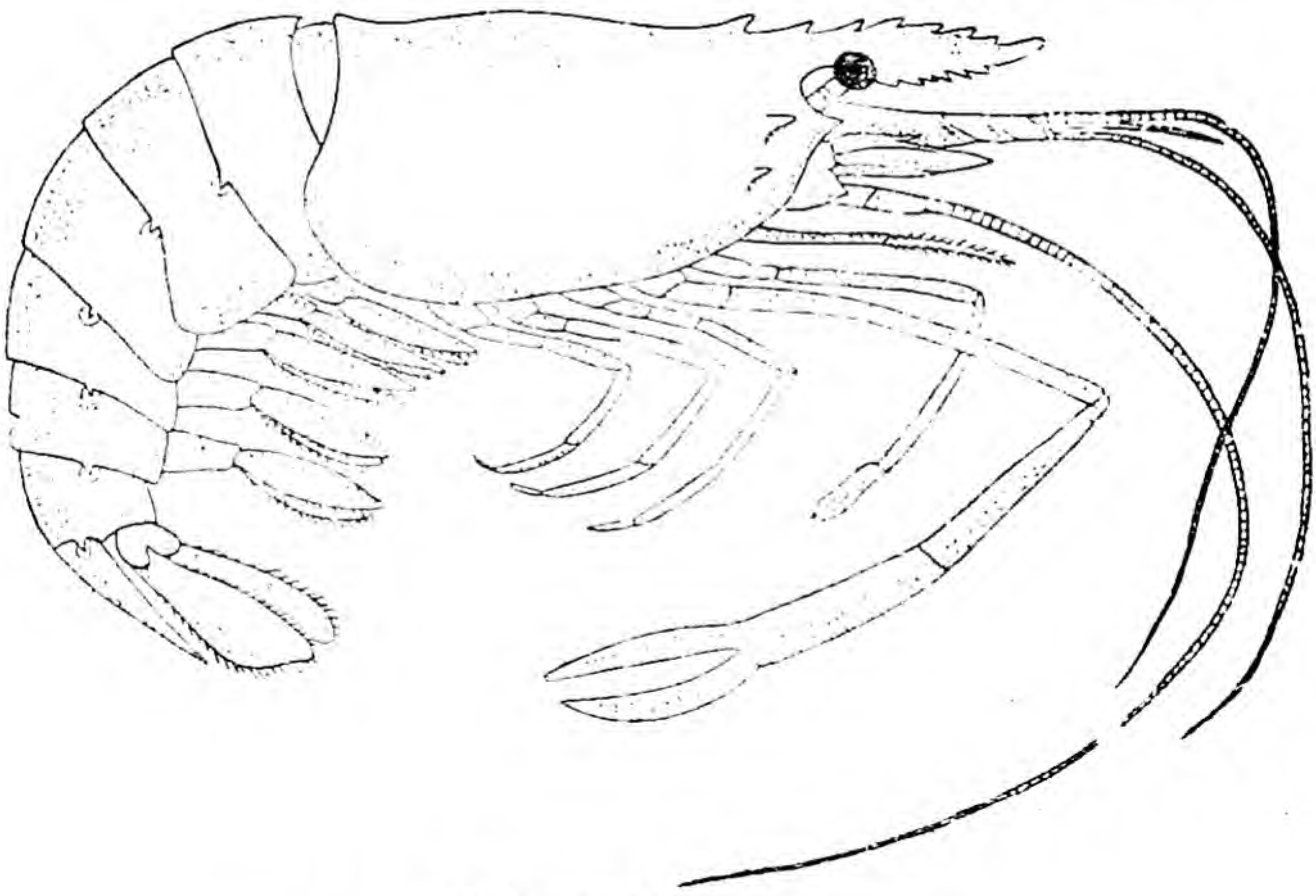
Crab. The crab (Fig. 33.1. B) has a broad cephalothorax. **Its** abdomen is very short, reduced and permanently bent under the ceph-



A—Water-flea (*Daphnia*) (Highly magnified)



Crab B—(*Paratelphusa*)



C—Prawn (*Palaemon*)

Fig. 33.1. Representatives of class Crustacea

alothorax. Both the pairs of antennae are very small. Crabs live in fresh and salt water.

Prawns. The prawns (Fig. 33.1 C) are found both in fresh and sea-water. The cephalothorax is smaller than the abdomen. The rostrum bears teeth on the upper and lower margins. Both the pairs of antennae are very long.

Class 2. Chilopoda It includes the centipedes. The body of a centipede is elongated and flattened dorsoventrally. It is segmented and bears a head in front The head carries a pair of antennae, a pair of mandibles and two pairs of maxillae. Each segment behind the head bears a pair of jointed legs. The first pair of legs are modified into **poison claws**. Respiration occurs by tracheae. Excretion takes place by Malpighian tubules. The development is direct.

Centipedes. The centipedes (Fig. 33.2) live in warm countries. They are nocturnal, terrestrial and carnivorous. Their food consists of

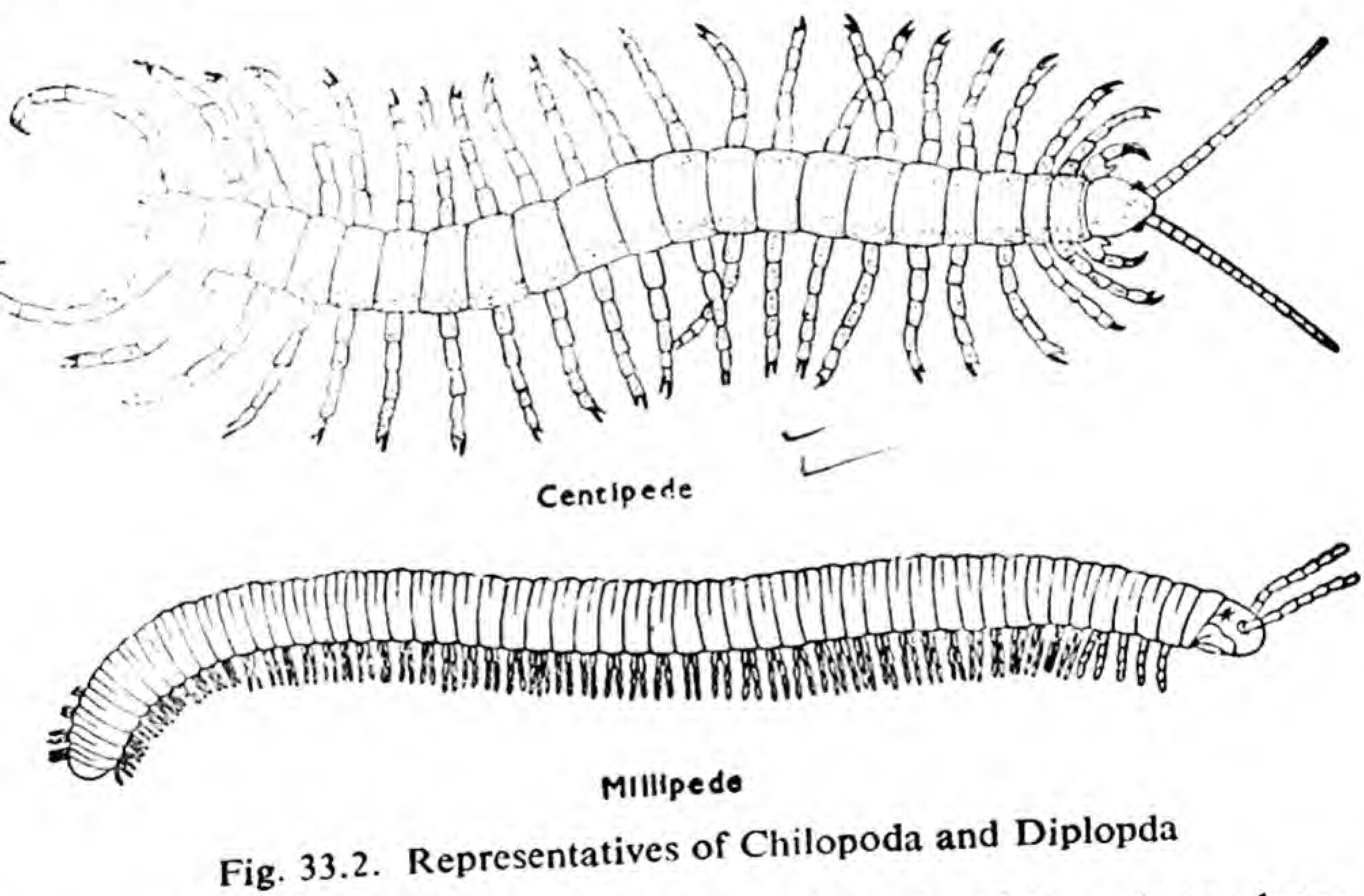


Fig. 33.2. Representatives of Chilopoda and Diplopda

insects, spiders and worms. The prey is killed with poison claws and chewed with mandibles. Their bite is very painful. Some centipedes are oviparous, others viviparous.

Class 3. Diplopoda. It includes the millipedes. The body is elongated and cylindrical. It is segmented and is divisible into three regions : head, thorax and abdomen. The head bears a pair each of antennae, mandibles and maxillae. The thorax consists of four (single) segments, each with a pair of legs except the first which is limbless. The abdomen consists of many (double) segments, each with two pairs of legs. Respiration occurs by **tracheae.** The development is direct.

Millipedes. The millipedes (**Fig. 33.2**) are terrestrial and inhabit

dark moist places under stones, logs and leaves. They are gregarious in habit. They usually feed on dead plant material. Some feed on living roots and damage vegetation. They usully roll into a spiral when disturbed. They have **stink glands** which secrete a foul smelling fluid. This fluid makes them unpalatable to their enemies. They move slowly in spite of the fact that they possess numerous legs. They are harmless creatures.

TABLE 12.

Differences between Centipedes and Millipedes

Centipedes	Millipedes
I. Habits	
1. Carnivorous.	1. Herbivorous and saprozoic.
2. Walk swiftly.	2. Walk slowly.
3. Oviparous or viviparous.	3. All oviparous.
4. Do not roll into a spiral when disturbed.	4. Roll into a spiral when disturbed.
II. External Characters	
5. Body dorsoventrally flattened.	5. Body cylindrical.
6. Two body-divisions : head and trunk.	6. Three body divisions ; head, thorax and abdomen.
7. Antennae long and tapering.	7. Antennae short and club-shaped.
8. Maxillae two pairs.	8. Maxillae one pair.
9. One pair of legs per segment.	9. One pair of legs per thoracic segment and two pairs per abdominal segment.
10. No legless segment.	10. First segment legless.
11. Legs arise laterally.	11. Legs arise close to mid-ventral line.
12. First pair of legs modified into poison claws.	12. First pair of legs resemble others.
13. Genital aperture single and posterior.	13. Genital apertures two and anterior.
14. Exoskeleton uncalcified.	14. Exoskeleton calcified.

Class 4. Insecta. It includes the insects. The body is divided into three parts : head, thorax and abdomen. The head bears a pair of antennae, a pair of mandibles and two pairs of maxillae. The

mandibles and maxillae collectively form the mouth-parts which are adapted for chewing, sucking or lapping. The head also bears a few simple eyes (ocelli) and a pair of compound eyes. The thorax consists of three segments and bears three pairs of legs ventrally and usually two pairs of **wings** dorsally. Some insects have a single pair of wings and some are even wingless. The abdomen comprises a number of segments (11 or less) and lacks appendages. Respiration occurs by **tracheae.** Excretion takes place by Malpighian tubules which open into the gut. Usually there is metamorphosis in the life-history.

The insects are found in all the habitats—water, land, air. They are, however, fewer in the ocean. Majority of them are free-living. Some are parasites on plants and animals. A few are colonial and social.

The class Insecta is the largest group in the animal kingdom. It includes about 675,000 species and, thus, forms 75% of the animal life existing at present. It is, therefore, quite appropriate to describe the present time as the age of insects.

The insects are most numerous and wide-spread of all the animals because of their special adaptations. Their tough chitinous exoskeleton protects them from injury and desiccation. Their power of flight enables them to explore new feeding grounds, find a suitable mate, escape from enemies and disperse their offspring. Their striated muscles provide quick movement. Their tracheal respiration very efficiently meets their energy requirements. Their well-developed sense organs enable them to pick up external stimuli quickly. Their rapid multiplication due to numerous eggs and short life-cycle contributes to the continuation of their race.

The class Insecta is divided into a large number of orders which are grouped into two sub-classes : Apterygota and Pterygota. The classification is based on three main characters, namely, nature of wings, type of mouth-parts and kind of metamorphosis.

Sub-class 1. **Apterygota**. It includes the primitive wingless insects with chewing or sucking mouth-parts and without metamorphosis. Its important order is Thysanura.

Order. Thysanura. It includes the three-pronged bristle tails. These insects have a small body covered with fine silvery **scales.** The mouth-parts are of the **chewing** type. The abdomen terminates in three long, slender processes, the lateral **anal circi** and the median **caudal appendage.** A well known example of the order is silver-fish.

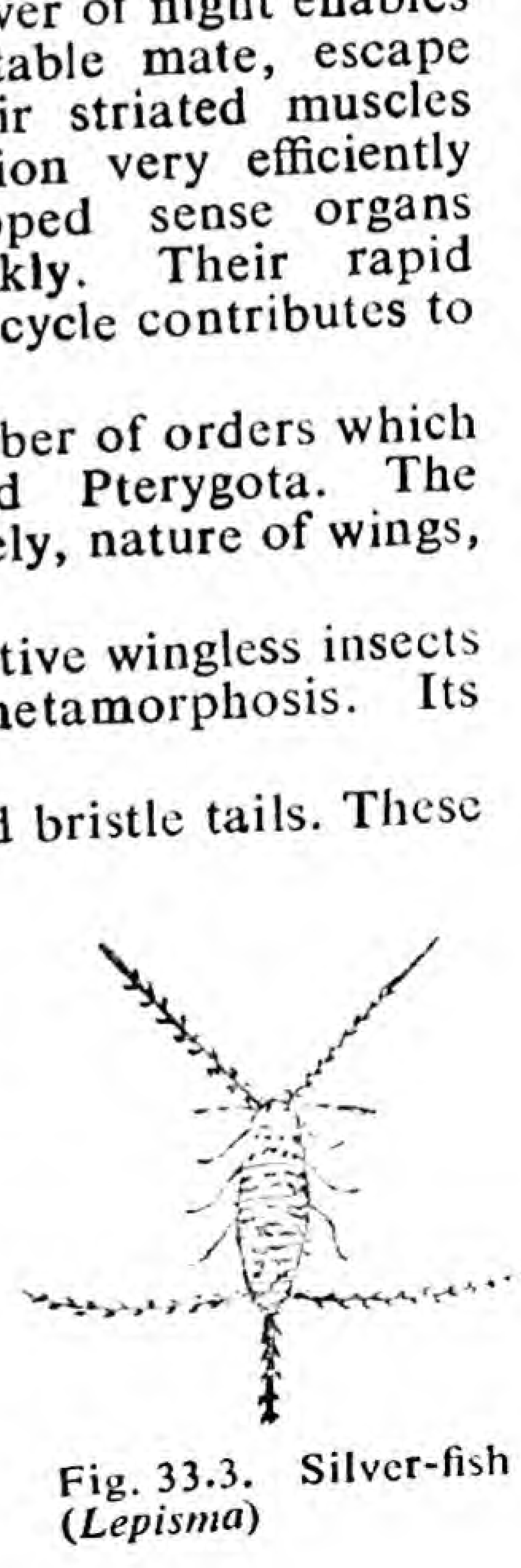


Fig. 33.3. Silver-fish (*Lepisma*)

Silver-fish (Fig. 33.3). The silver-fish is found among the old books, behind the wall papers and pictures, and in the clothes. It has a flat body covered with shining silvery scales. **It is** about 12 mm. long. It feeds on the starch used in book-binding and starching clothes. It is a harmful insect.

Sub-class 2. **Pterygota**. It includes the winged or secondarily wingless insects with varying types of mouth-parts and metamorphosis. Its important orders are—Orthoptera, Dictyoptera, Phasmida, Isoptera, Odonata, Anoplura, Homoptera, Hemiptera, Coleoptera, Lepidoptera, Diptera, Siphonaptera and Hymenoptera.

Order (*i*) **Orthoptera**. It includes the grasshoppers and locusts. These insects possess two pairs of wings. The fore-wings are narrow, thick and parchment-like. They serve to cover the hind-wings when the insect is not flying. They are, therefore, known as the wing-covers or tegmina (singular tegmen). The hind-wings are broad, membranous and folded like a fan when at rest. They act as the organs of flight. The wings are reduced or absent in certain forms. The mouth-parts are of the chewing type. Metamorphosis is gradual. The cerci are unjointed.

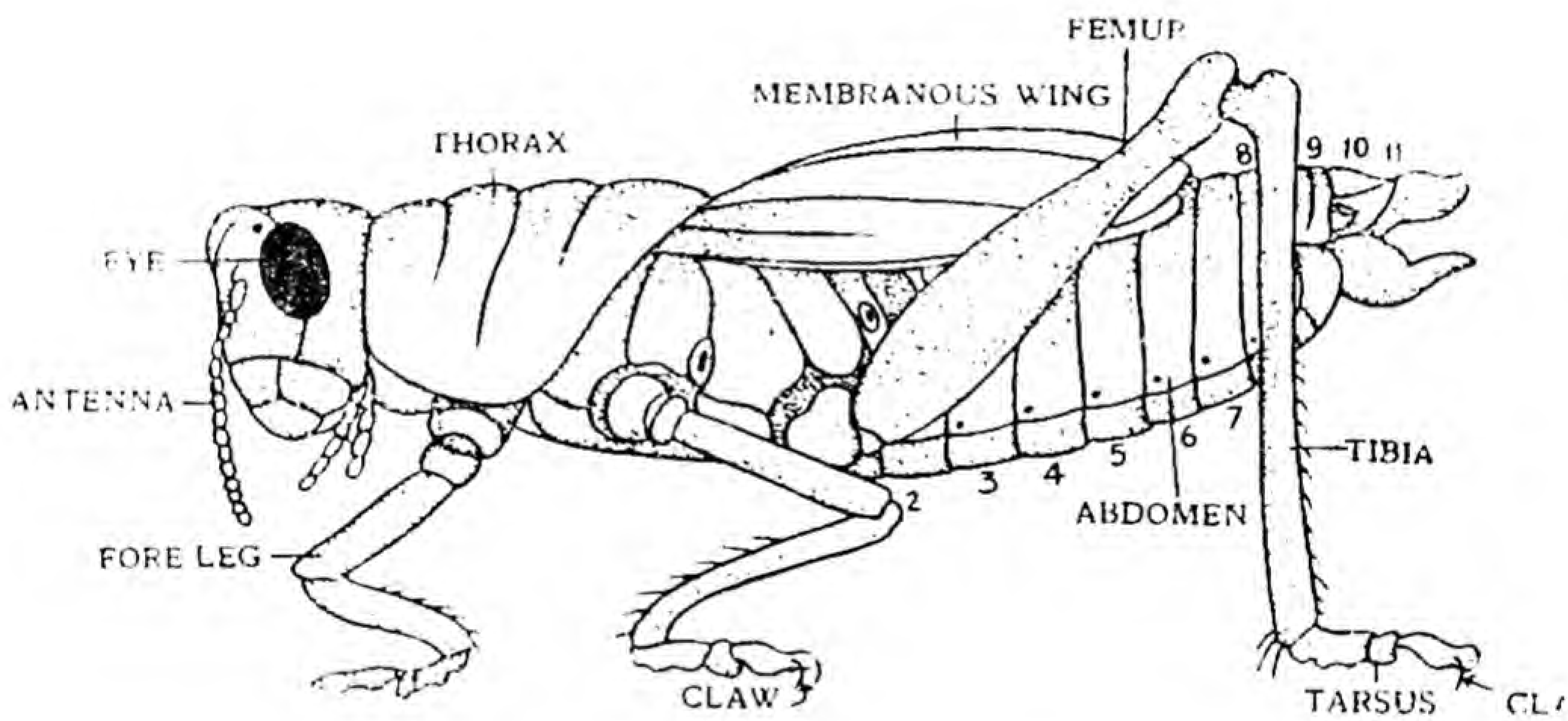


Fig. 33.4. Grasshopper

Grasshopper. The grasshoppers (Fig. 33.4) have a long cylindrical body of various colours. The hind-legs are adapted for jumping. They are diurnal and feed on green leaves. The males produce sound by rubbing the posterior legs against the fore-wings or by rubbing the edges of the two wings of each side. The grasshoppers often damage crops.

Locust. The locusts are like the grasshoppers in structure and mode of life but they do not stay at one place. When they do not find food or find the place too hot to stay, they migrate in huge swarms to a new place, eating the crops in the way. They are serious plant pests. There are several species of locusts. The desert locust (*Schistocerca gregaria*) is yellow in colour with dark spots on the fore-wings. It inhabits Arabia, Persia, Southern Afghanistan and Baluchistan. From these

places, it often invades India and causes large-scale destruction of field crops.

Order (*ii*) **Dictyoptera**. It includes the cockroaches and praying mantides. They resemble the grasshoppers in their wings, mouth-parts and metamorphosis but have 5-jointed tarsi and many-jointed cerci.

Praying Mantis (Fig. 33.5) The praying mantis is a predaceous insect. It feeds on insects and spiders. It does not run after the prey. It waits for the prey, sitting at a place with the enlarged grasping fore-legs raised. In this position, it appears as if absorbed in offering prayer, hence its name. The moment the prey comes within its reach, it suddenly catches it. It is in fact a "preying mantis." It also practises cannibalism. It is a useful insect as it destroys harmful insects.

TABLE 13

Differences between Grasshoppers and Cockroaches.

Grasshoppers	Cockroaches
1. Occur on plants in fields, lawns, gardens and along road-sides.	1. Inhabit kitchens, hotels, bakeries, grocer's shops, fruit stalls, railway wagons, ships and sewers.
2. Some diurnal, others nocturnal.	2. All nocturnal.
3. Herbivorous.	3. Omnivorous.
4. Males produce sound.	4. Do not produce sound.
5. Body cylindrical.	5. Body flattened.
6. Antennae short or long.	6. Antennae very long.
7. Metalegs very large for jumping.	7. All legs almost similar.
8. Tarsi 3 or 4 jointed.	8. Tarsi 5-jointed.
9. Cerci unjointed.	9. Cerci many jointed.
10. Walk slowly, jump and fly.	10. Run fast, rarely fly.
11. Ovipositor well developed and uncovered.	11. Ovipositor reduced and concealed.
12. Eggs deposited in the ground in masses called egg-pods.	12. Eggs laid in covers called oothecae.

Order (*iii*) **Phasmida**. It includes the stick and leaf insects. They show protective resemblance. In wings, mouth-parts and metamorphosis,

they resemble the first two orders.

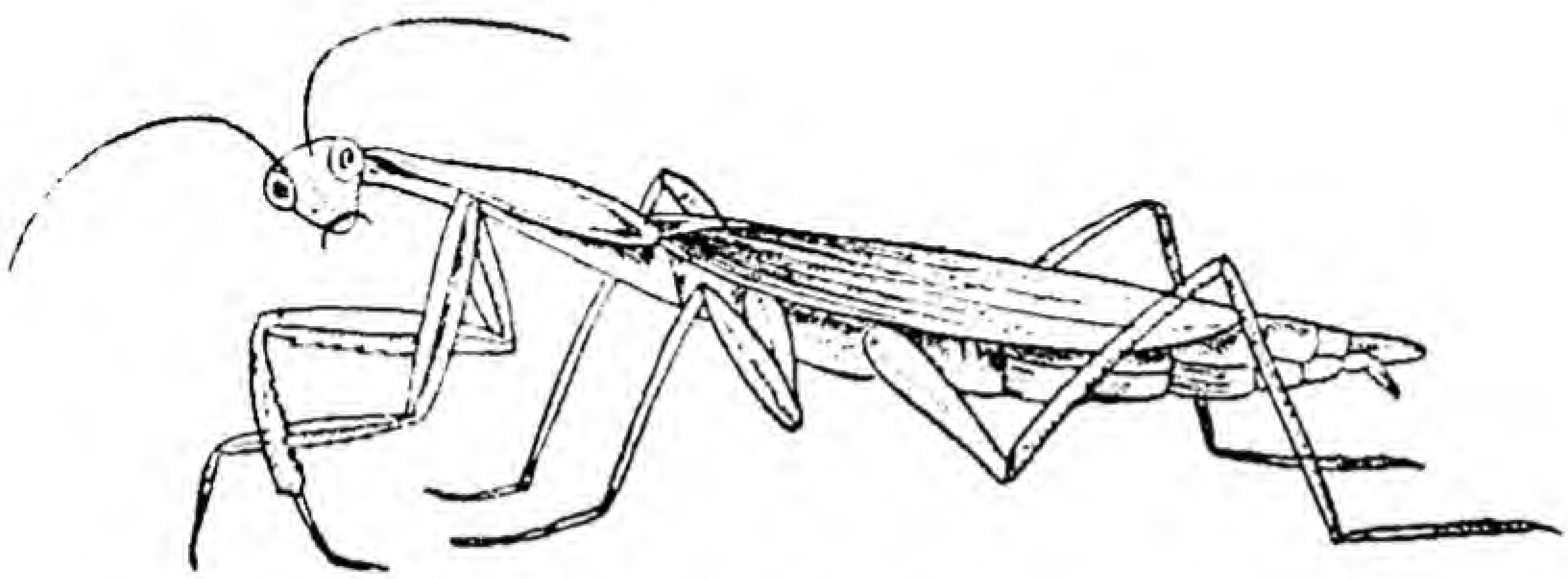


Fig. 33.5. Praying-mantis

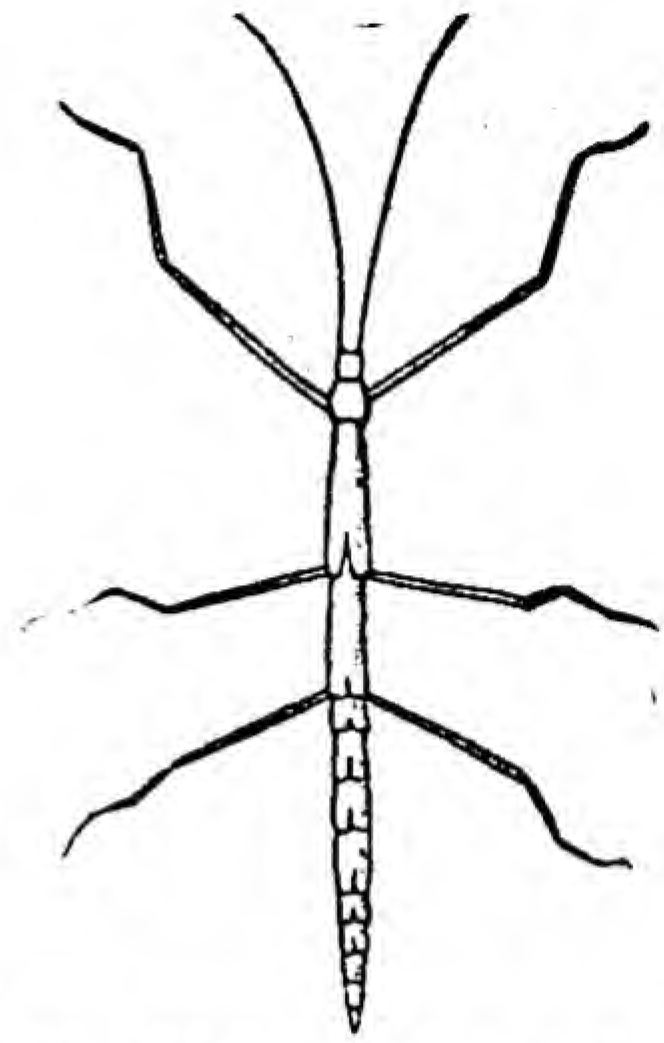


Fig. 33.6. Stick insect

Stick-insect (Fig. 33.6). The stick-insects have a long, slender body looking like a twig on which they rest. They walk very slowly. From their movements it appears as if sticks or twigs are walking. They are, therefore, also called the walking-sticks. They have reduced or no wings. Their antennae legs and meso- and metathorax are long. They feed on leaves.

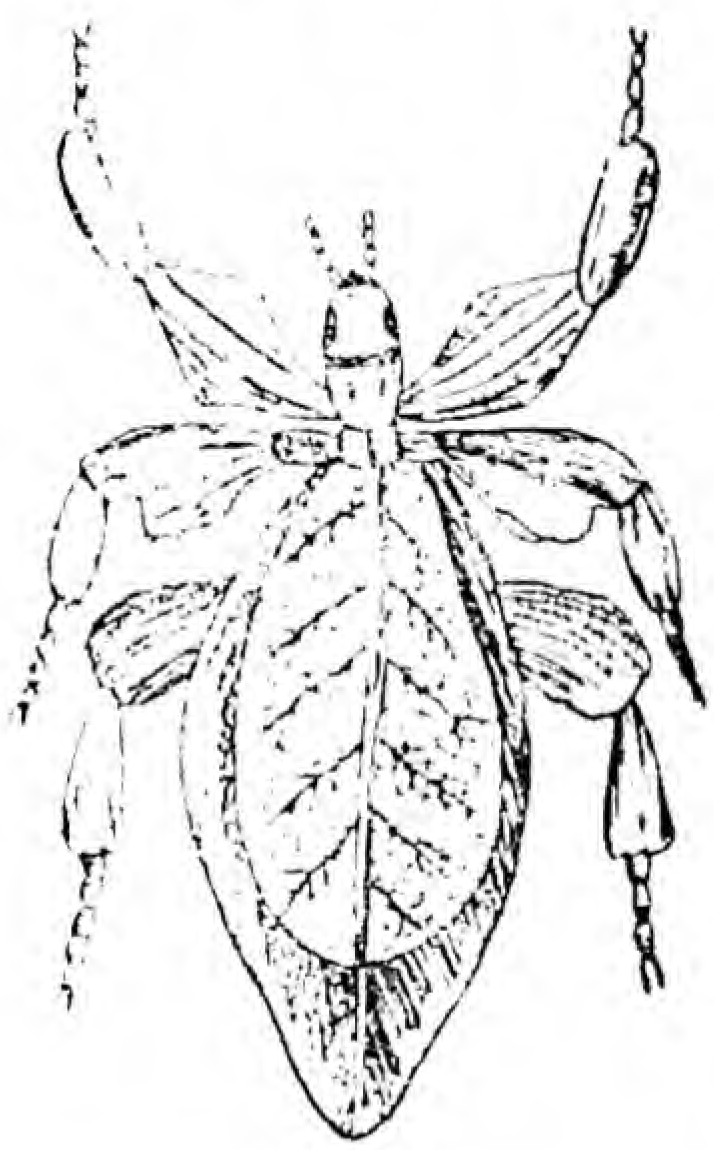


Fig. 33.7. Leaf-insect

Leaf-insect (Fig. 33.7). In the leaf-insects the body, wings and even legs are flattened like a leaf, hence their name. Moreover, their wings are veined like the leaves.

Order (*iv*). **Isoptera.** It includes the termites or white ants. The wings, when present, are in two pairs. They are long, narrow, membranous and alike, hence Isoptera. The mouth-parts are of the chewing type. Metamorphosis is gradual.

Termites (Fig. 33.8). The termites abound in the tropical and warm temperate countries. They are small soft-bodied insects. They are social and polymorphic. They live in colonies. Their nest or **termitarium** may be entirely undergound or may project above the ground as a small hill or mound. It is built of sand particles cemented together by saliva or faeces. It has many chambers and gallaries. A colony of termites consists of a female or **queen**, a male or **king** and numerous **workers** and **soldiers**. The workers and soldiers are wingless, blind and colourless, hence white-ants. The queen and king may be winged or wingless. The sole function of the queen is to lay eggs. The king fertilizes the

queen. The workers collect food, prepare nest, look after the eggs and nymphs and attend upon the queen and the king. The soldiers defend the colony from the invaders. For this they have a large head and strong jaws.

In the rainy season, winged males and females leave the nest and fly away to new sites. This is called **swarming**. At the new places, the wings are shed and mating occurs. One male and one female together start a new colony. They dig out a small burrow in which the female lays eggs. The eggs hatch into the workers which soon take up their responsibilities. The queen now grows to an enormous size and continues laying eggs for a long time.

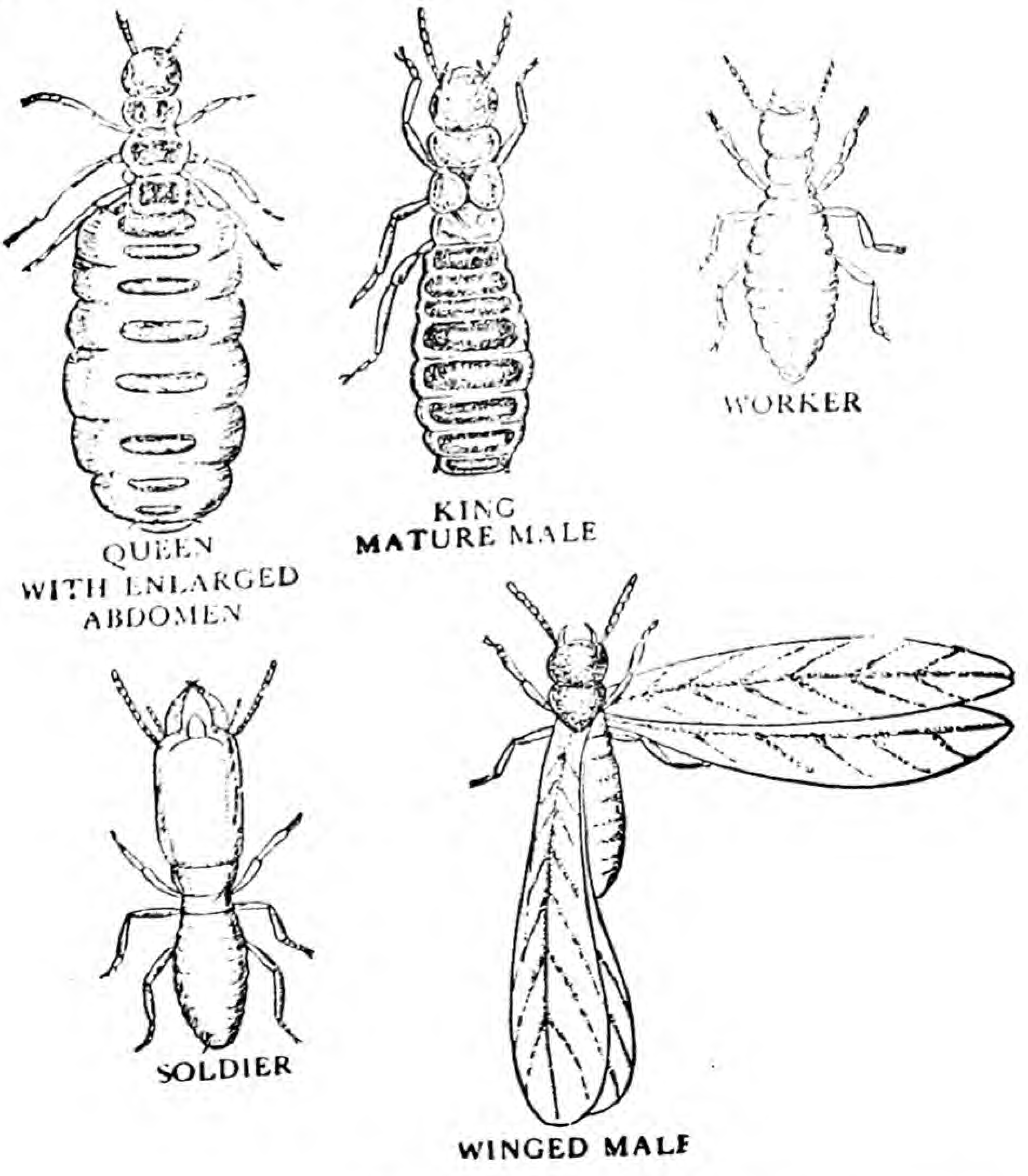


Fig. 33.8. Termites

The termites are highly destructive insects. They damage furniture, books, buildings, bridges, poles, etc.

Order (*v*) **Odonata.** It includes the dragon-flies and damsel-flies. These insects have two pairs of transparent membranous wings. The mouth-parts are of the chewing type. Metamorphosis is incomplete.

The dragon-flies (Fig 33.9) and damsel-flies (Fig. 33.10) are seen flying over ponds and streams containing aquatic vegetation in summer. They have a variously coloured body, with large mobile head, very short antennae, and huge eyes. They are predaceous and capture the prey (mosquitoes and flies) during flight with the legs. The young or naiads are aquatic and respire with gills. The naiads feed on the larvae of mosquitoes and other insects.

Fig. 33.9. Dragon-fly

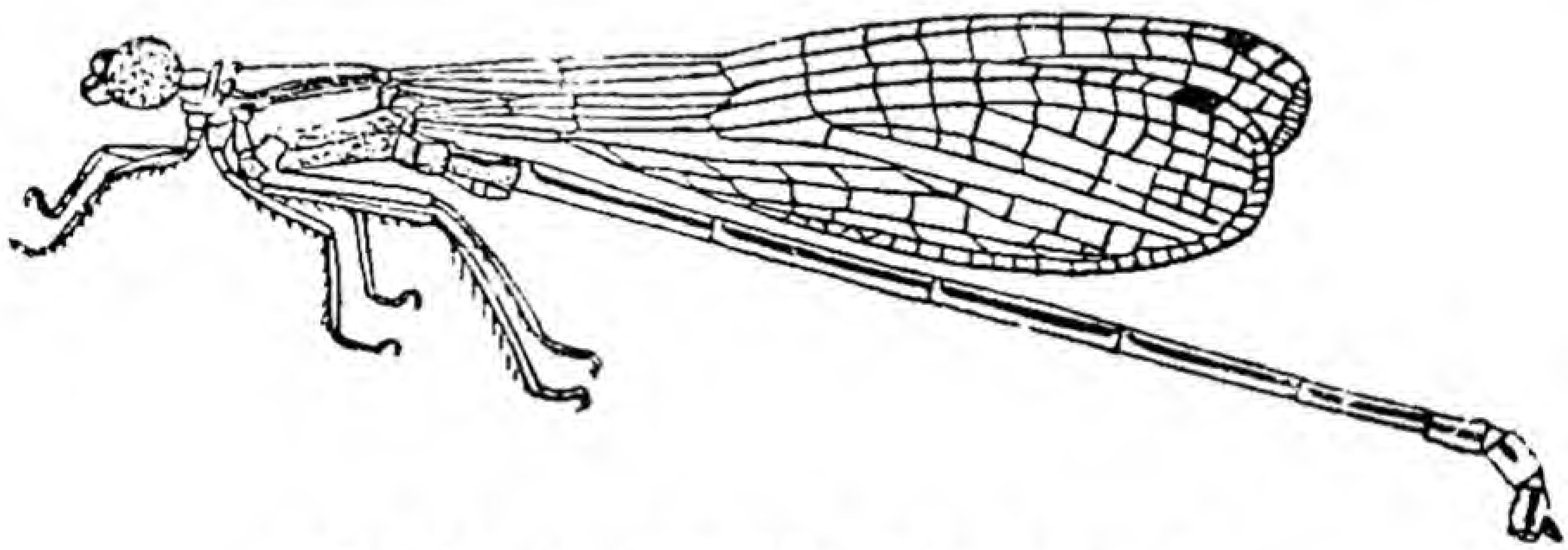


Fig. 33.10. Damsel-fly (After Kennedy)

TABLE 14.

Differences between Dragon-flies and Damsel-flies

Dragon-flies	Damsel-flies
1. Body is stoutly built.	1. Body is slender and delicate.
2. Eyes meet in the middle line over the head.	2. Eyes do not meet each other.
3. Hind-wings are wider at the base than the fore-wings.	3. Fore- and hind-wings are equally broad at their bases.
4. Keep their wings extended laterally when at rest.	4. Keep their wings folded vertically over the back when at rest.
5. Naids have gills in the rectum for respiration. They draw and expel out water at intervals to wash the gills.	5. Naids have three leaf-like gills at the hind-end of the abdomen.
6. Fast fliers.	6. Slow fliers.

The dragon and damsel flies are beneficial to man as they and their naiads feed on harmful insects. Their naiads also serve as food for fishes.

Order (*vi*) **Anoplura**. It includes the sucking lice. These insects have no wings. The mouth parts are of the piercing-sucking type, Metamorphosis is gradual. The body is small and flat with legs ending in curved claws for clinging. The lice are ectoparasites of mammals.

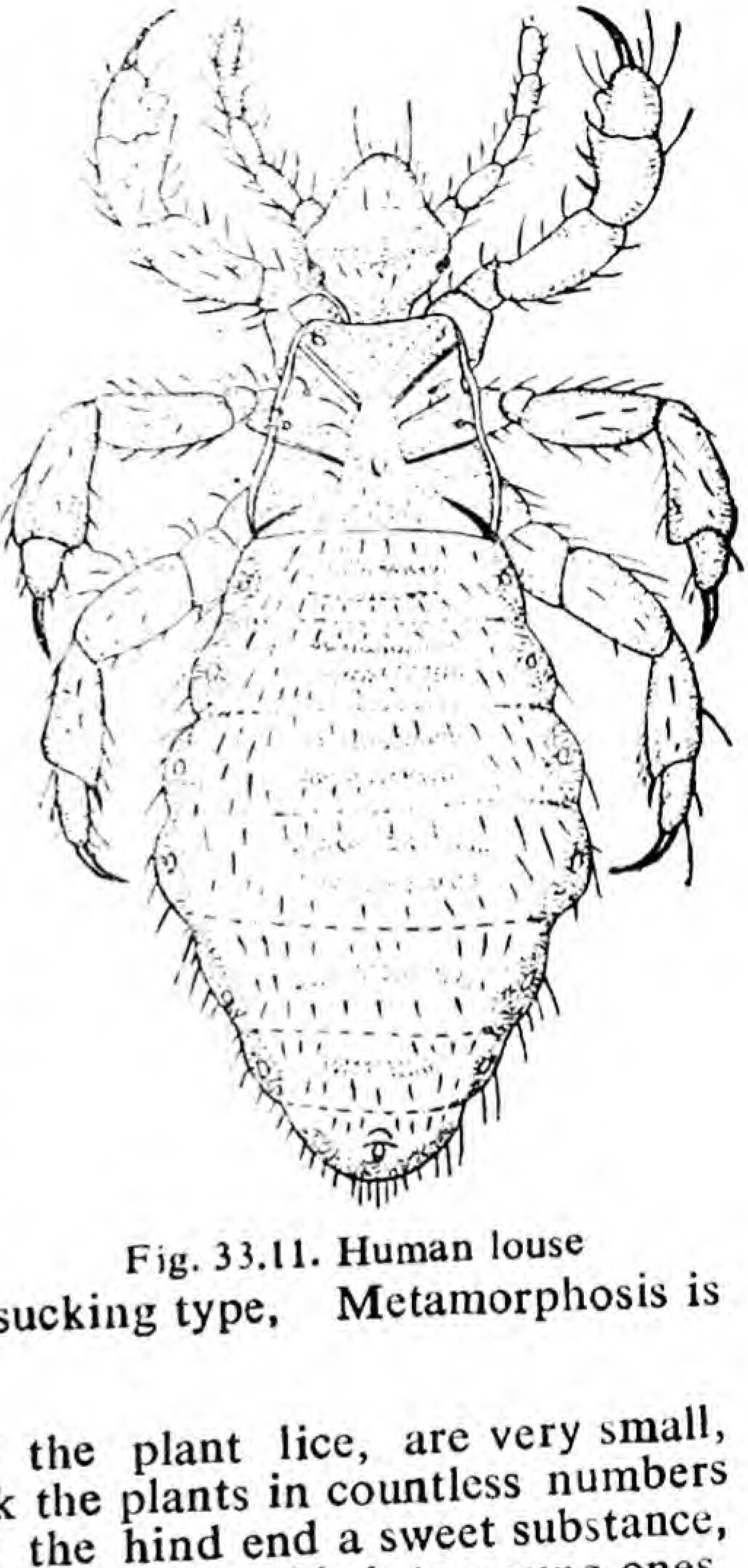


Fig. 33.11. Human louse

Human Louse. (Fig. 33.11). The human louse is common in unclean communities. The adult female lays several hundred eggs which are attached to the body hair by a cementing substance. Young lice hatch in a week and become adult after three months. Besides sucking blood and causing irritation, these lice also carry germs of typhus, relapsing and trench fevers.

Order (*vii*) **Homoptera**. It includes cicades, leaf-hoppers, plant lice or aphids and scale insects. These insects have two pairs of membranous wings which are held sloping over the body when at rest. The females of certain forms are wingless. The mouth-parts are of piercing-sucking type, Metamorphosis is gradual.

Aphids. The aphids, also called the plant lice, are very small, usually wingless insects. They attack the plants in countless numbers and suck their sap. They secrete from the hind end a sweet substance, the **honeydew**, which is eaten by ants. They give birth to young ones. They often show **parthenogenesis**, *i.e.* the development of the young without fertilization. The cabbage aphid (Fig. 33.12) is a common example.

Order (*viii*) **Hemiptera**. It includes the bugs. These insects have two pairs of wings. The fore-wings are thick and horny at the base and membranous behind where they overlap each other during rest. They are called **hemelytra**. The hind wings are membranous. Some bugs are wingless. The mouth-parts are of the piercing-sucking type. Metamorphosis is gradual.

Bed-bug (Fig 33.1:). The bed-bugs are small wingless insects with a flat, oval, dark-brown body. They have a peculiar foul smell. They are nocturnal and blood-suckers, feeding on the blood of man and other

warm-blooded animals. A well-fed bedbug can do without food for several months.

Plant Bugs. The plant bugs include some serious pests, *e.g.* the red cotton bug (Fig. 33.14). It has red and black colour with a white ring behind the head. It is 12-15 mm. long. The adults as well as the nymphs suck juice from the cotton bolls and destroy them. It also attacks sweet-potato, tobacco, lady's finger, etc.

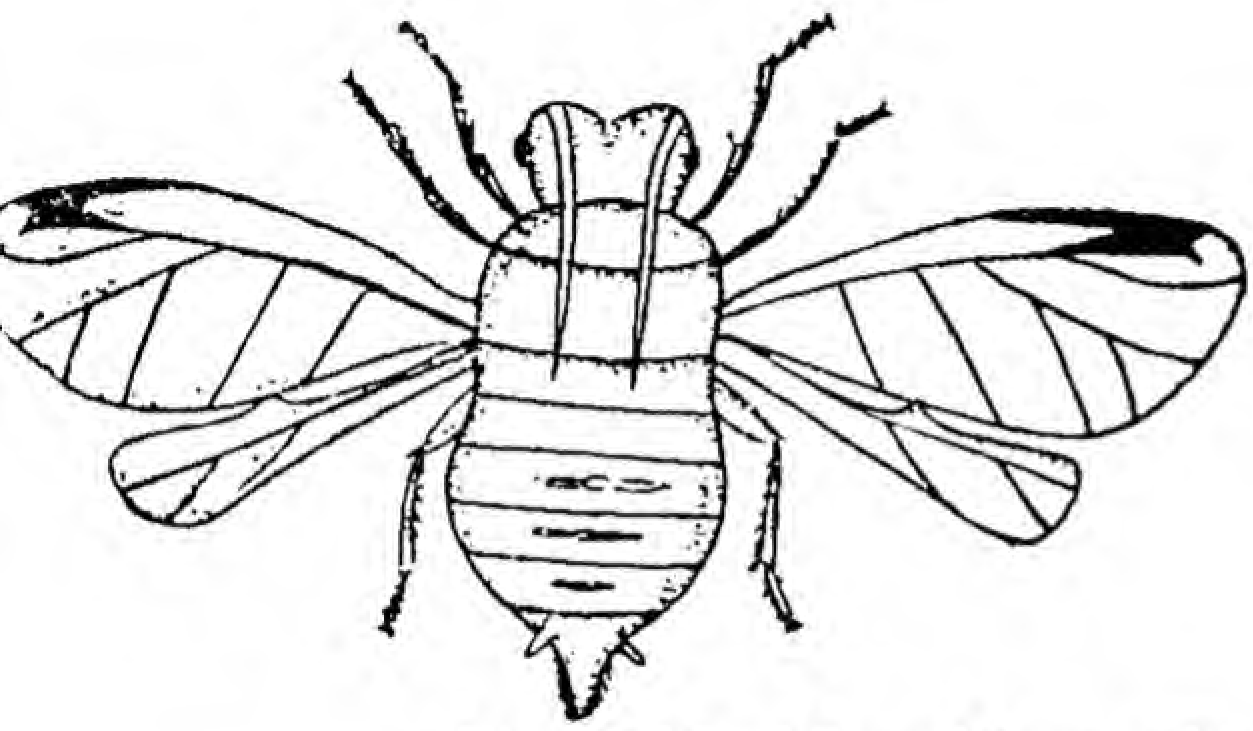


Fig. 33.12. The cabbage aphid

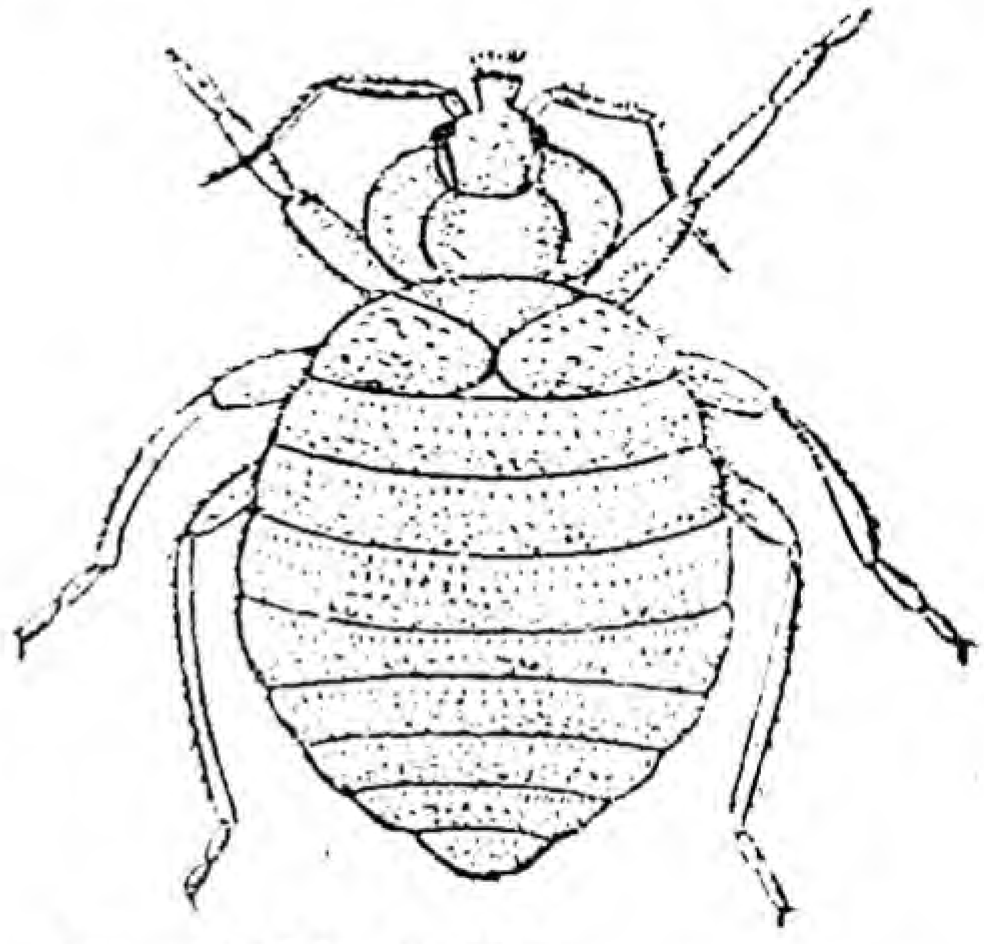


Fig. 33.13. Bedbug

Order (*ix*) **Coleoptera.** It includes the beetles and weevils. These insects have two pairs of wings. The fore-wings are thick, horny, veinless and meet in a straight line over the back. They serve only as the wing-covers and are called the **elytra**. The hind-wings are membranous and folded beneath the fore-wings, when at rest. They act as the organs of flight. The mouth-parts are of the chewing type. Metamorphosis is complete. The larvae are worm-like, usually have 3 pairs of legs and are called the **grubs**. The common examples are the hadda beetle and rice weevil.

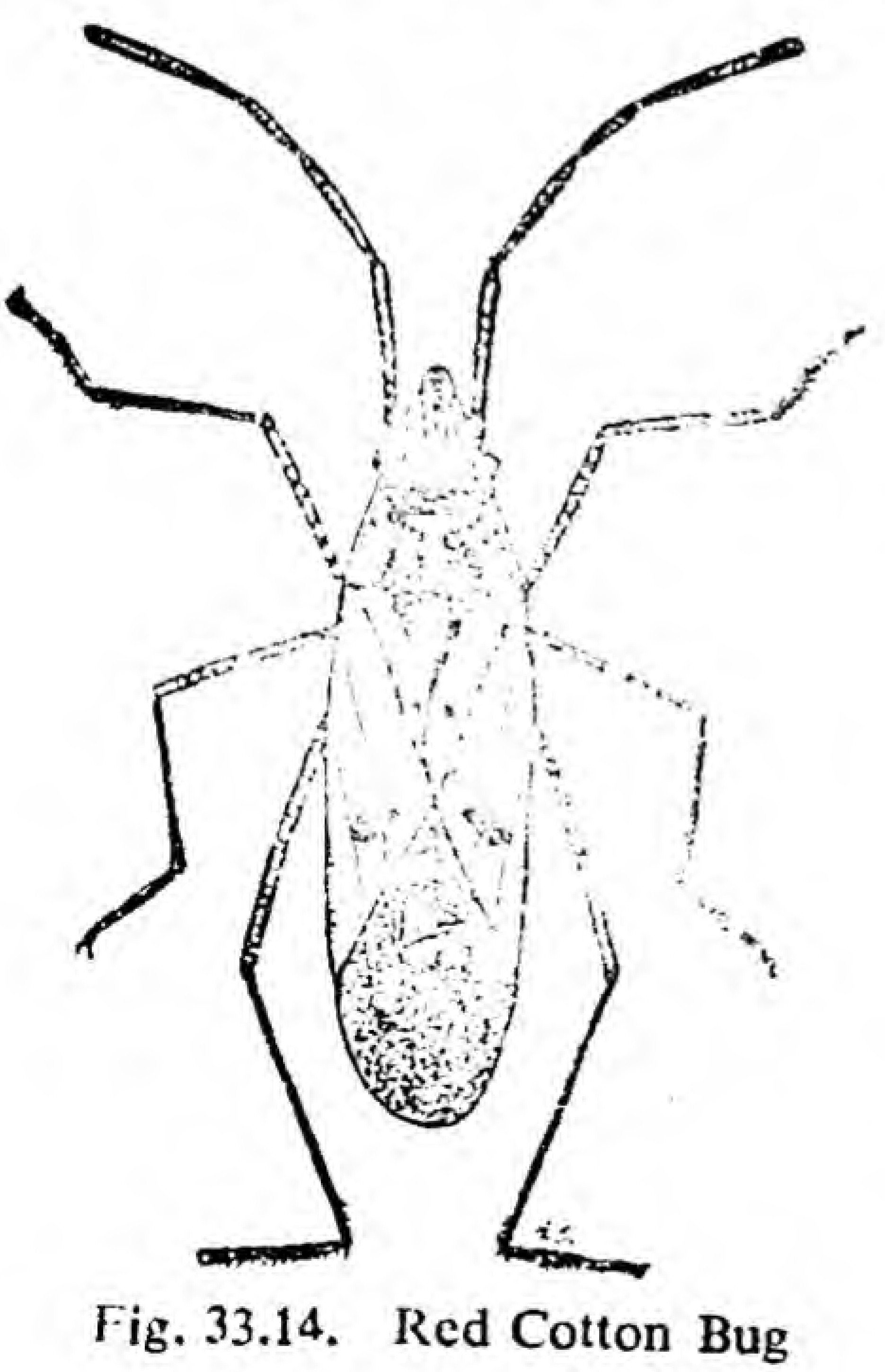


Fig. 33.14. Red Cotton Bug

Hadda Beetle (Fig. 33.15). The hadda beetle has a hemispherical reddish-brown body bearing 12 black spots. It is a pest of brinjal plants.

Rice Weevil (Fig. 33.16). The rice weevil is a small dark-brown insect with a pointed snout in front. It lays eggs on the grains like rice, wheat, corn, etc. The legless larvae eat their way into the grains where they feed and grow into the adults. It is a pest of stored grains.

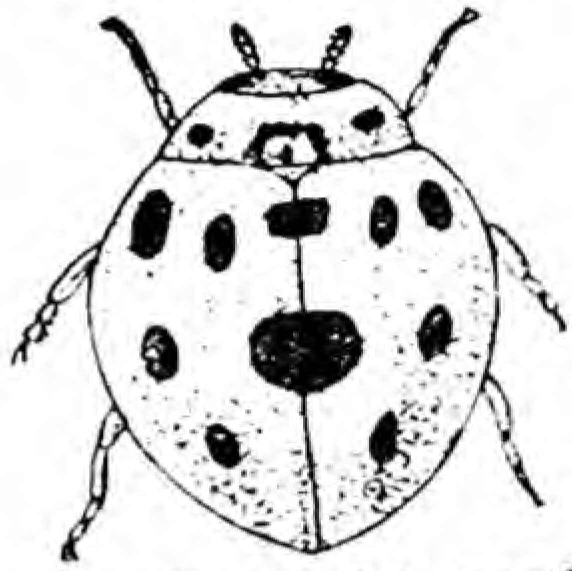


Fig. 33.15. Hadda beetle

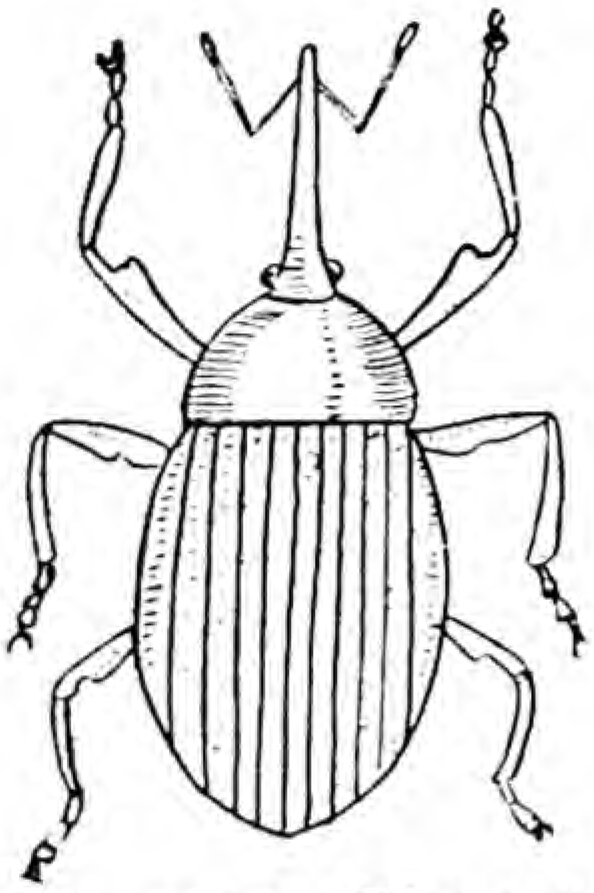


Fig. 33.16. Rice weevil.

TABLE 15.

Differences between Bugs and Beetles

Bugs	Beetles
1. Body flat dorsally.	1. Body prominently convex dorsally.
2. Fore-wings half thick and half thin (hemelytra); cross each other at rest.	2. Fore-wings uniformly thick, leathery, veinles and concave (elytra), meet along the middle line.
3. Hind-wings folded fan-wise under the hemelytra.	3. Hind wings folded forwards under the elytra.
4. Mouth-parts piercing-sucking.	4. Mouth-parts chewing.
5. Metamorphosis gradual.	5. Metamorphosis complete.

Order (x) **Lepidoptera.** It includes the butterflies and moths. These insects have two pairs of broad membranous wings covered with shining coloured **scales**. The scales come off as dust on the finger when touched. The mouth-parts are of the siphoning type in the adults for sucking nectar from the flowers They form a long proboscis which is coiled like a watch-spring, when not in use. Metamorphosis is complete. The larvae are worm-like and possess three pairs of true legs on the thorax and five pairs of pro-legs on the abdomen. They are called **caterpillars**. The caterpillars have chewing mouth-parts for feeding on leaves and tender shoots

The butterflies and moths are useful in pollination. Their caterpillars are, however, very destructive to crops.

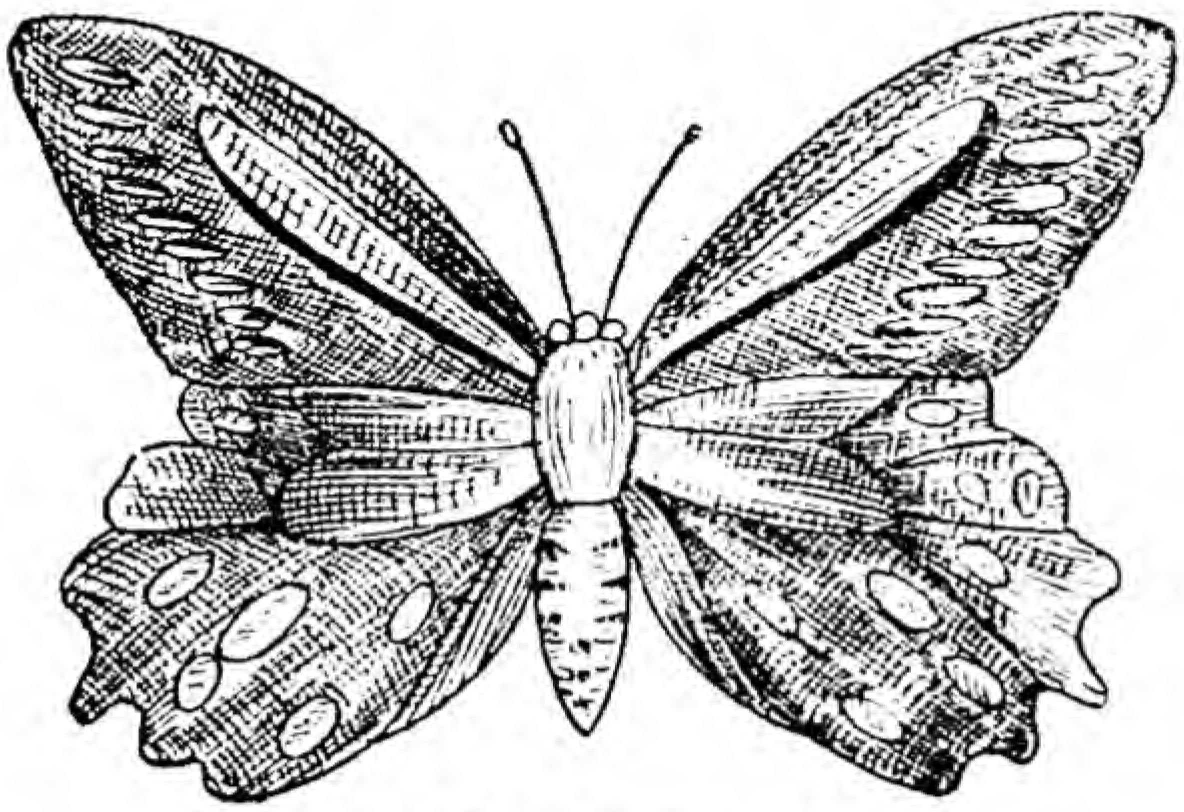


Fig. 33.17. Butterfly

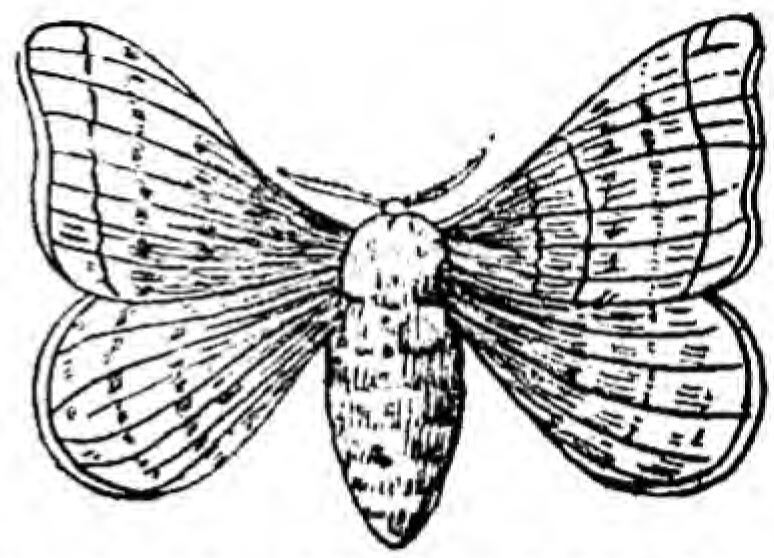


Fig. 33.18. Silk moth (Male)

TABLE No. 16.

Differences between Butterflies and Moths

Butterflies	Moths
1. Active during the day (diurnal)	1. Active during the night (nocturnal).
2. Keep their wings vertically above the body when at rest, their upper surfaces meeting.	2. Keep their wings flat over the back when at rest.
3. Body slender, usually with constriction between thorax and abdomen.	3. Body robust and hairy, no constriction between thorax and abdomen.
4. Antennae knobbed.	4. Antennae tapering.
5. No ocelli.	5. Ocelli often present.
6. Wings of each side are inter-locked during flight by an expanded membrane near the base of the hind-wings.	6. Wings of each side are inter-locked during flight by bristles on the hind-wings.

Order (*xi*) **Siphonaptera.** It includes the fleas. These insects lack wings. The mouth-parts are of the piercing-sucking type. Metamorphosis is complete.

Fleas (Fig. 33.19). The fleas are ectoparasites of warm-blooded animals like poultry, rats, cats, dogs, goats, and men. They have a small, tough, laterally-compressed body bearing bristles all over. The antennae are very short and lie in a groove. The eyes are simple or absent. The legs are long and adapted for jumping. They lay eggs in the habitat of or on the host. The minute legless larvae feed on decaying organic matter. The pupae undergo metamorphosis in silken cocoons. The adults feed on blood. They spread bubonic plague from the rat to man.

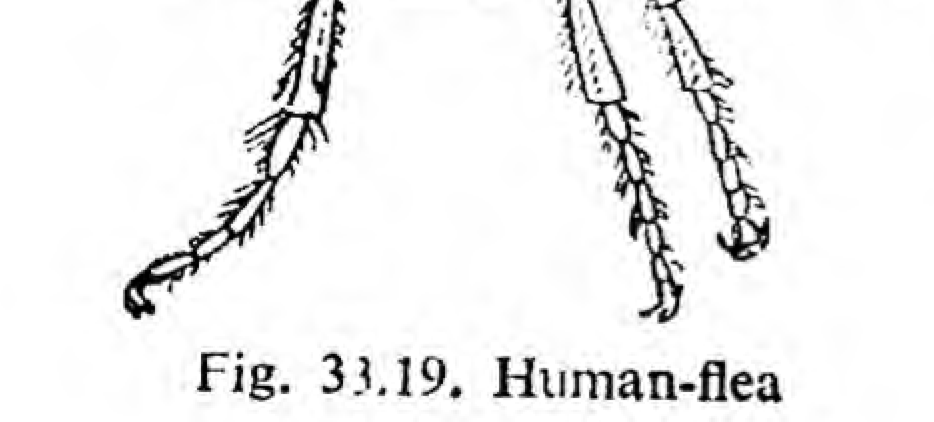


Fig. 33.19. Human-flea

Order (*xii*) **Diptera.** It includes flies and mosquitoes. These insects have only one pair of wings, the fore-wings, which are membranous. The hind-wings are represented by small knob-like structures, the **halteres** or **balancers**. The mouth-parts are of the sponging or piercing-sucking type and often form a **proboscis.** Metamorphosis is complete. The larvae are worm-like and without legs. They are called **maggots.**

Flies. The flies are harmful insects. The house-fly (***Musca***) carries germs of cholera, dysentery, typhoid, etc. from the faeces, sputum and filth to the human food. The germs (bacteria) are carried on the hairy body, legs and mouth-parts. The use of contaminated food infects man.

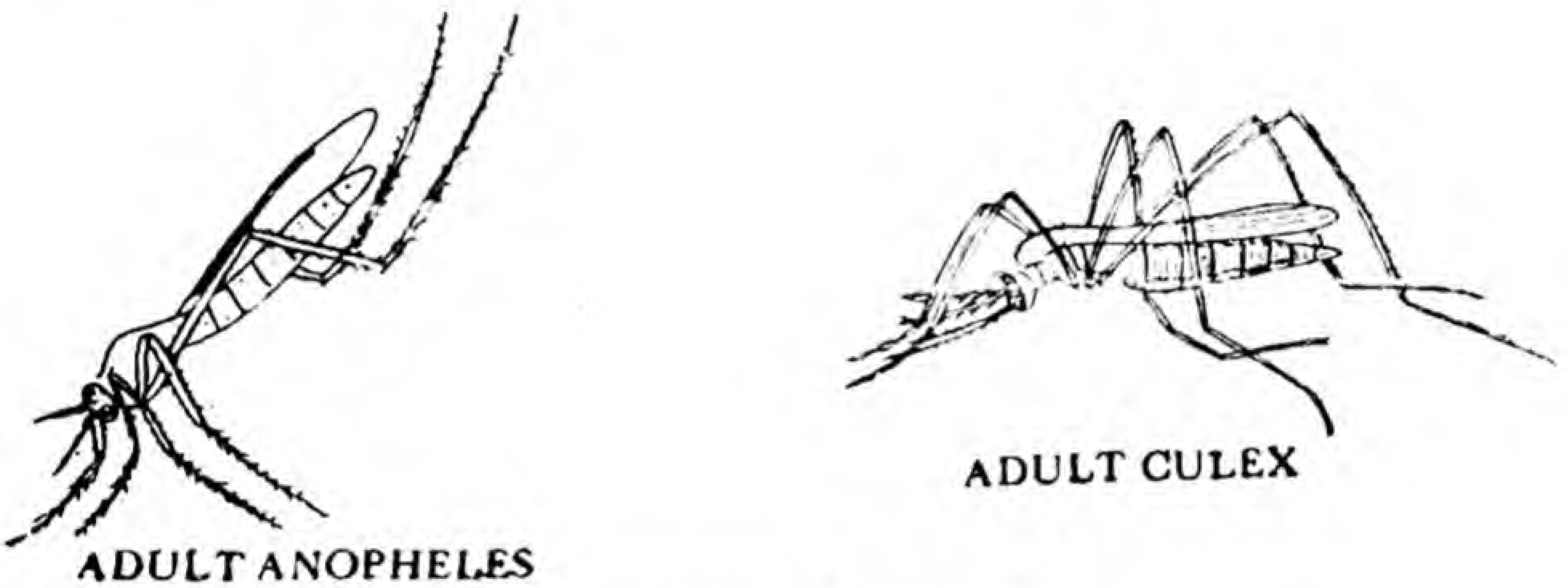


Fig. 33.20. Mosquitoes

Mosquitoes (Fig. 33 20). The mosquitoes have a slender humped body. The wings are fringed with scales. Proboscis is well-developed. The males suck plant sap while the females chiefly suck blood of warm-blooded animals, birds, and mammals. The larvae are aquatic with respiratory siphon. The pupae are motile. All the mosquitoes are annoying but some spread diseases also, *e.g. Culex* spreads filariasis and *Anopheles* spreads malaria.

TABLE 17.

Differences between Culex and Anopheles

Culex	**Anopheles**
I. **Egg** 1. Eggs are laid in a mass, the egg-raft.	1. Eggs are laid singly.
2. Eggs are cigar-shaped, have no floats.	2. Eggs are pointed at each end and have a pair of lateral floats each.
3. Eggs lie vertically with the thicker end downward.	3. Eggs float horizontally.

Culex	Anopheles
II. **Larva**	
4. Larva has a long respiratory siphon on the 8th abdominal segment.	4. Larva lacks a respiratory siphon. Instead, it has a pair of spiracles on the 8th abdominal segment.
5. Larva rests obliquely with the head downward and respiratory siphon projecting out.	5. Larva rests horizontally in water with spiracles protruding out.
III. **Pupa**	
6. Pupa has long respiratory siphons.	6. Pupa has short respiratory siphons.
IV. **Adult.**	
7. Adult keeps its body parallel to the surface when at rest.	7. Adult makes an angle with the surface when at rest.

Order (*xiii*) **Hymenoptera.** It includes the bees, wasps and ants. These insects have two pairs of membranous wings. The fore- and hind-wings are interlocked during flight. Some forms are wingless. The mouth-parts are of the chewing or chewing-lapping type. Metamorphosis is complete.

Honey-bee (Fig. 33.21). The honey-bee is a social, polymorphic, colonial insect. The colony consists of three castes : a fertile female or **queen,** a few males or **drones** and numerous sterile females or **workers.** The comb or hive hangs vertically from a tree, building or rock. It is formed of secretion from the abdominal glands of the workers. It consists of two layers of hexagonal chambers or cells. Some of the chambers are packed with honey and pollen. They are called the **storage cells.** In others the young ones are brought up. They are known as the **brood cells**. The various castes perform different functions in the hive. The queen only lays eggs. The drones fertilize the queen. The workers make and repair the hive, clean it, ventilate it by vibrating their wings, collect food (nectar and pollen) from the flowers, rear the young ones and feed the queen. When the colony becomes overcrowded, the old queen leaves the hive along with some workers and drones. They fly to a new place to establish another colony. This is called **swarming**. New queen is then formed in the old colony. She soon undertakes a **marriage** or **nuptial** flight with the drones. Mating occurs in the air. The queen, after mating, returns to the hive and starts laying eggs. She does not leave the hive again till she becomes old when swarming occurs.

The honey-bee provides honey and bee's wax. It is the best pollinator among the insects. The workers sting.

Wasps. (Fig. 33.23). The wasps are also social insects. They build their nests from wood which is thoroughly chewed and made into a

pulp. The nest is attached to the ceiling of a room or arch of varandah by a short stalk. The colony consists of a queen, drones and workers.

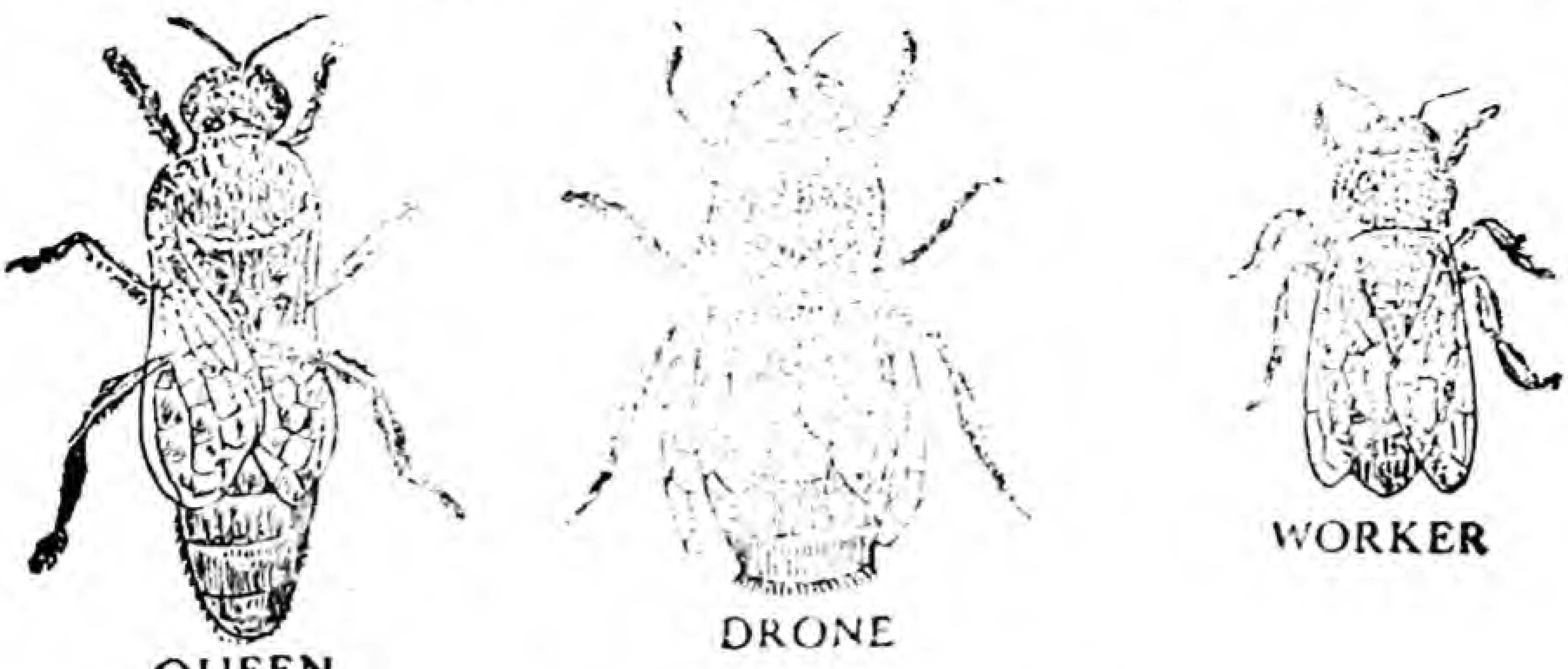


Fig. 33.21. Honey-bee

Only the queen, somehow, survives the winter. In spring it starts preparing a nest and lays eggs in it. The eggs hatch into workers which take up their duties.

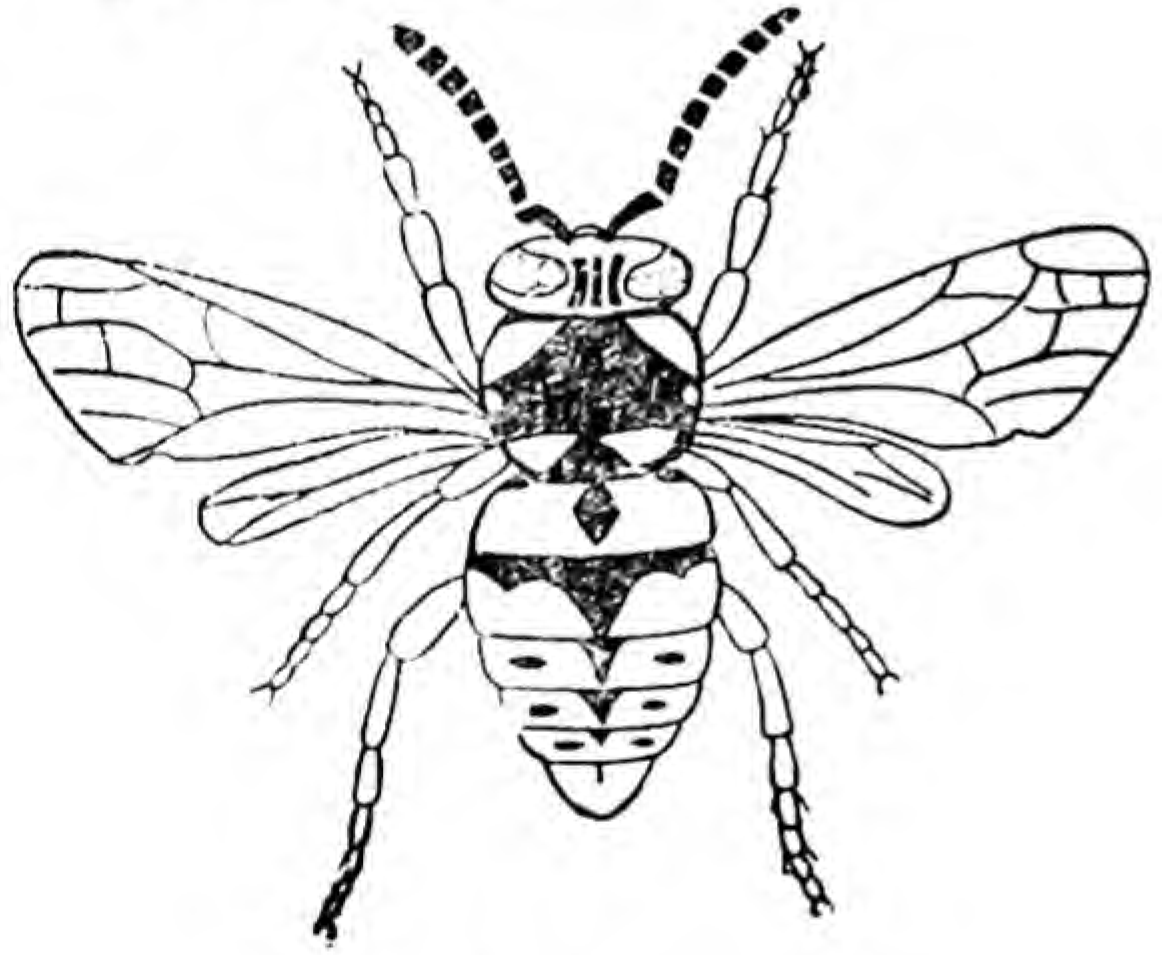


Fig. 33.22. Wasp

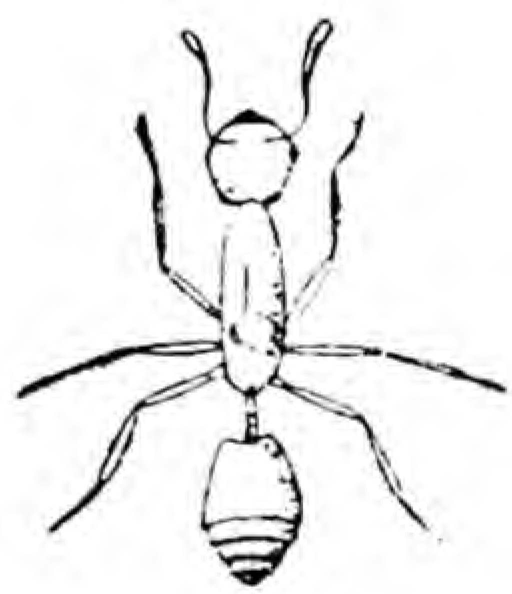


Fig. 33 23 Ant

Ants (Fig. 33.23). The ants are also social insects. They make nests in the ground or hollow tree trunks. They are usually scavengers and dispose off the dead organic matter. They are harmful also because they collect and damage seeds in the fields and pollute all sorts of eatables in the houses.

Class. 5. Arachnida. It includes the spiders, scorpions, ticks and mites. The body usually consists of two parts : the cephalothorax and abdomen. The cephalothorax bears two pairs of mouth parts : the chelicerae and **pedipalpi**, for capturing and tearing the prey, and four pairs of **walking legs**. The antennae and true jaws are missing. The eyes are simple. The abdomen lacks appendages. Respiration occurs by tracheae or book-lungs. The **book-lungs** are sacs containing lamellae

like the leaves of a book. Excretion takes place by Malpighian tubules or green glands or both. The development is usually direct.

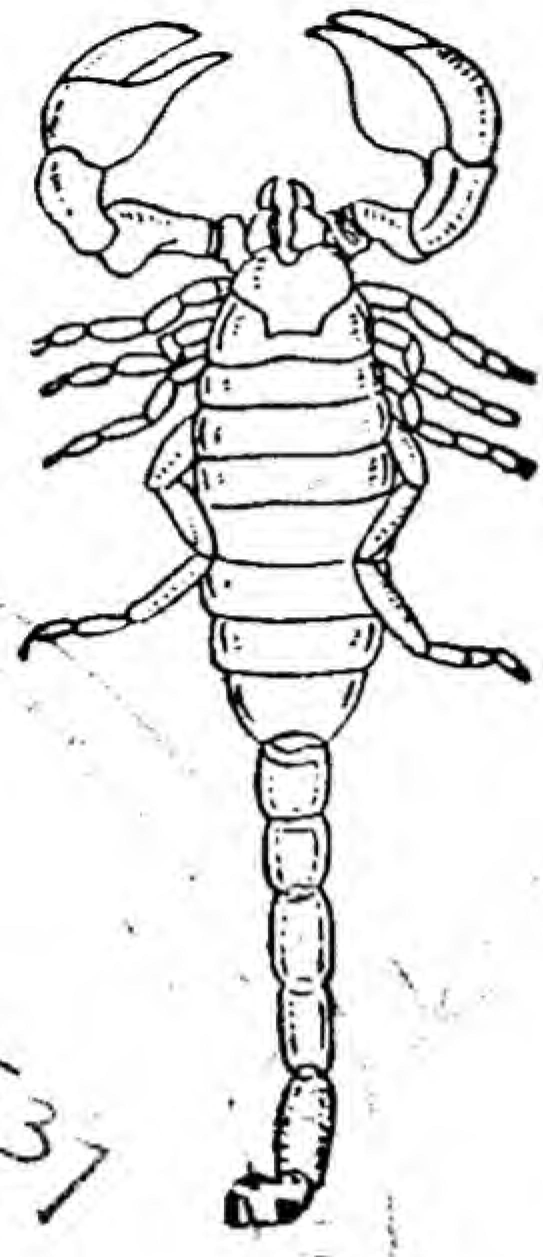


Fig. 33.24. A scorpion

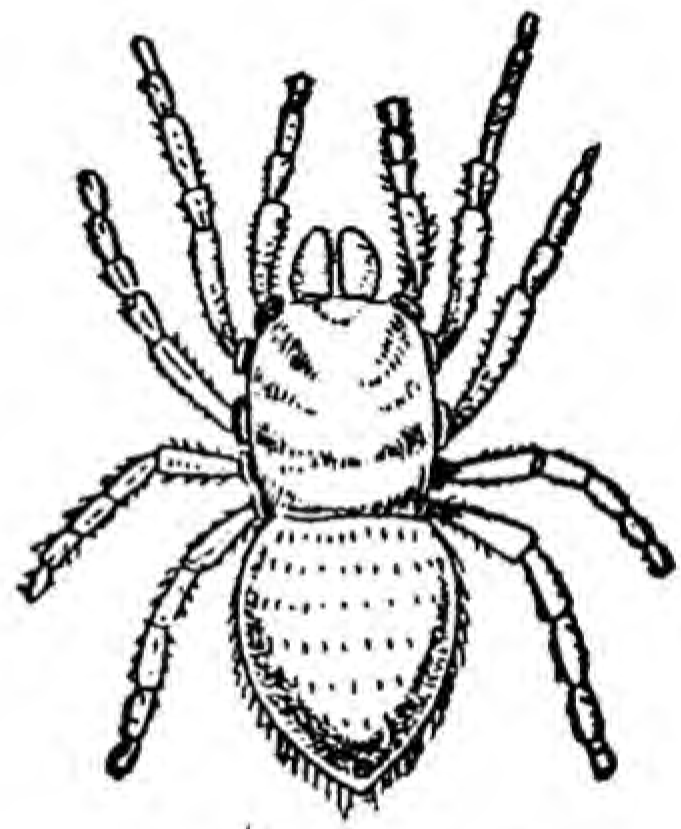


Fig. 33.25. A spider

The arachnids are mostly terrestrial and are abundant in warm dry regions. The majority are free-living. A few are parasites.

Scorpions. The scorpions (Fig. 33.24) are found in the warm countries. They are nocturnal creatures. They feed on insects, spiders and worms. They perform an interesting courtship dance. The pedipalpi of the female are held by those of the male and the tails of the two are raised and intertwined above them. They now walk together in a ring several times. In this operation, the male retreats and drags the female after it. Finally, the male digs a burrow and both enter it. The male is usully eaten up by the female after mating. She is **viviparous** and carries the young on the back for some time after birth.

The abdomen of a scorpion is differentiated into broader **preabdomen** and narrower **post-abdomen** raised upwards. The post-abdomen **ends in a poison vesicle** which carries a curved spine or **sting**. The sting **is used** for killing or paralysing the prey and also for defence.

Spiders. The spiders (Fig. 33.25) live in all habitats and are common in the houses and gardens. They feed on insects, sucking only fluid from their bodies. The prey is captured in various ways. The hunting spiders run it down in a chase or jump over it stealthily. Other spiders entrap the prey in webs made of silk threads which are secreted by special abdominal glands. The web shows a great variety of form in different species. The familiar geometrical web of the garden spider is a wonderful piece of spider architecture.

The spiders show sexual dimorphism. The males are much smaller than the females. During mating, the male very carefully approaches the female because he is likely to be eaten up if she is not in a mood to receive him. Even when accepted, he may be killed and eaten up after copulation.

The spider has unsegmented abdomen and a flattened cephalothorax, the two joined by a narrow waist.

TABLE 18

Differences between Spiders and Insects

Spiders	Insects
1. Have two body divisions : cephalothorax and abdomen.	1. Have three body divisions : head, thorax and abdomen.
2. Show no trace of segmentation.	2. Show segmentation in thorax and abdomen.
3. Lack antennae.	3. Have a pair of antennae.
4. Have simple eyes.	4. Have compound as well as simple eyes (ocelli).
5. Mouth parts include paired chelicerae and pedipalpi.	5. Mouth parts include a labrum, a pair of mandibles, a pair of maxillae, a labium and a hypopharynx.
6. Mouth parts adapted for sucking.	6. Mouth parts variously adapted for chewing, sucking, siphoning, sponging, etc.
7. Lack wings.	7. Usually have one or two pairs of wings.
8. Have 4 pairs of legs.	8. Have 3 pairs of legs.
9. Have spinnerets for producing silk thread.	9. Lack spinnerets.
10. Genital opening anterior on second abdominal segment.	10. Genital opening at posterior end of abdomen.
11. Development is direct.	11. Development usually with larval stages and metamorphosis.
12. All are carnivorous and useful to man.	12. May be herbivorous, carnivorous, omnivorous and useful or harmful to man.

IV. Economic Importance

Crustacea. Many crustaceans provide human food, directly or indirectly. The larger forms like lobsters, cray-fish and prawns are eaten in various parts of the world. The smaller forms like water-fleas are fed upon by many fishes and other aquatic animals, which ultimately reach our table. The crustaceans are harmful also. Some serve as intermediate hosts for human parasites. *Cyclops* carry larvae of a nematode, the Guinea worm, and a cestode, the broad tapeworm. The crabs and cray-fish harbour larvae of the lung-fluke. A few crustaceans, if present in large numbers, act as crop pests, *e.g.* the cray-fishes damage cotton plants. A wood-boring crustacean, the gribble, damages wharves in the sea by burrowing in them.

Chilopoda. The Chilopoda may be regarded as beneficial to man as they feed on insects, some of which are injurious. Larger forms inflict painful bites which may result in headache, dizziness and fever. The smaller forms are harmless.

Diplopoda. The Diplopoda are of little economic importance. Most of them are scavengers and dispose off the dead organic matter. Some feed on plant roots and cause damage in green-houses and gardens.

Insecta. The insects are useful to man in the following ways :—

1. They give us many substances of commercial importance, *e.g.* honey and bee's wax are produced by the honey-bee, silk by silkworms, shellac by lac insects, cochineal (a red pigment) by cactus scale insect, cantharidine by spanish fly, etc.

2. Insects aid in the production of fruits, seeds and vegetables by pollinating the flowers. The more important pollinating insects are bees, wasps, ants, butterflies, moths, bugs and beetles.

3. Insects form human food. Insects like grasshoppers, locusts, crickets, aquatic bugs and many more are eaten by human beings in certain parts of the world.

4. Insects form food for animals useful to us. Many animals that come to our table as food subsist on insects, *e.g.* fish, chickens, turkey and hogs.

5. Insects act as scavengers. Carrion beetles bury human faeces and cattle dung in the ground. The flesh flies lay eggs in the animal carcases which are completely eaten up by their maggots in no time. Ants dispose off all sorts of dead organic matter.

6. Insects destroy other injurious insects. Dragon flies feed on mosquitoes, lady-bird beetles eat up plant-lice, praying mantides consume many harmful insects and so on.

7. Insects destroy weeds by feeding on them.

8. Insects promote soil fertility by making burrows in it and by adding their faeces and dead bodies to it.

9. Insects are employed in scientific studies. Cockroach, Ak grass-hopper and fruit-fly are abundantly used as laboratory animals for scientific learning and research.

10. Insects have aesthetic and entertaining value too. Brightly-coloured forms are used as ornaments in trays, rings and necklaces. Crickets are reared as pets by Orientals. Some insects have served as subject-matter for poems.

Insects are also harmful to man in many ways :—

1. They destroy field crops, fruit trees and timber plants. The more destructive insects are locusts, grasshoppers, beetles, caterpillars, aphids, leaf-hoppers, scale-insects, bugs and weevils.

2. They damage stored grains, *e g*. grain weevils and ants.

3. They spoil useful articles in the houses, *e.g*. silver-fish damages books, white-ants destroy furniture, cloth-moths eat up clothes, carpet beetles damage fur, woollens and feathers, wood-boring beetles destroy furniture, cockroaches and ants pollute food, and so on.

4. They spread diseases among human beings. The more important disease-carriers are house-fly, mosquitoes, lice, sand-fly, tse-tse fly and bugs.

5. They spread diseases among domestic animals and useful plants.

6. They annoy man in various ways. Bees and wasps sting ; mosquitoes, lice and fleas bite and suck blood ; small insects fall into the eyes.

Arachnida. The arachnids are mainly harmful to man. Scorpions and a few spiders are poisonous and sting. Certain mites damage crops, *e.g*. the blister mite (*Eriophyee*) injures buds and fruits of apple, pear and grapes. The ticks feed on the blood of man and his domestic animals. They also carry disease-causing Protozoa responsible for Taxas fever in cattle, tick fever in man and so on. A few mites also attack man and domestic animals, *e.g*. the itch mite (*Sarcoptes scabei*) penetrates into human skin and causes severe irritation. The sheep and chicken mites destroy sheep and fowls. Spiders and scorpions are beneficial to a certain degree as they feed largely on injurious insects.

V. Summary

Phylum **Arthropoda** (ar-throp-o-da) : Animals with jointed legs, externally segmented body, chitinous exoskeleton.

Class 1. **Crustacea** (kra-stay-sha) : Two pair of antennae, *e.g*. *Palaemon*, cray-fish, crab.

Class 2. **Chilopoda** (ky-lop-o-da) : Long flat body, one pair of legs per segment, *e.g*. centipede.

Class 3. **Diplopoda** (dip-lop-o-da) : Long cylindrical body, most segments with 2 pairs of legs each, *e.g*. millipede.

Class 4. **Insecta** (in-sek-ta) : 3 pairs of legs, usually two pairs of wings, one pair of antennae.

Sub-class (*a*) **Apterypgota** (a-ter-ee-go-ta) : Primitive wingless insects.

Order (*i*) **Thysanura** (thy-sa-neyo-ra) : Mouth-parts chewing, *e.g.* silver-fish.

Sub-class (*b*) **Pterygota** (ter-ee-go-ta) : Typically winged insects.

Order (*i*) **Orthoptera** (or-thop-ter-a) : Fore-wings thick, hind thin, mouth-parts chewing, metamorphosis gradual, *e.g.* grasshopper, locust.

Order (*ii*) **Dictyoptera** (dik-teop-ter-a) : Forewings thick, hind thin, mouth-parts chewing, metamorphosis gradual, cerci many-jointed, *e.g.* cockroach, praying mantis.

Order (*iii*) **Phasmida** (Fas-me-da) : Fore-wings thick, hind thin, mouth-parts chewing, metamorphosis gradual, show protective resemblance, *e g.* leaf and stick insects.

Order (*iv*) **Isoptera** (eye-sop-ter-a) : Social, sexual forms with like wings, mouth-parts chewing, metamorphosis gradual, *e.g.* termites.

Order (*v*) **Odonata** (o-do-nay-ta) : Two pairs of thin wings, mouth-parts chewing, metamorphosis incomplete, *e.g.* dragon-fly, damsel-fly.

Order (*vi*) **Homoptera** (ho-mop-ter-a) : Wings 4, 2 or none, mouth-parts piercing-sucking, metamorphosis gradual, *e.g.* aphid.

Order (*vii*) **Hemiptera** (he-mip-ter-a) : Fore-wings half thick and half-thin, mouth-parts piercing-sucking, metamorphosis gradual, *e.g.* bugs.

Order (*viii*) **Coleoptera** (ko-lee-op-ter-a) : Fore-wings very thick and veinless, mouth-parts chewing, metamorphosis complete, *e.g.* beetles, weevils.

Order (*ix*) **Lepidoptera** (le-pi-dop-ter-a) : Wings covered with coloured scales, mouth-parts siphoning, metamorphosis complete, *e.g.* butterfly, moth.

Order (*x*) **Siphonaptera** (sy-fan-ap-ter-a) : No wings, mouth-parts piercing-sucking, metamorphosis complete, *e.g.* fleas.

Order (*xi*) **Diptera** (dip-ter-a) : Only fore-wings, mouth-parts sponging or piercing-sucking, metamorphosis complete, *e.g.* flies, mosquito.

Order (*xii*) **Hymenoptera** (hy-men-op-ter-a) : Wingless or with two pairs of thin wings, mouth-parts chewing or chewing-lapping, metamorphosis complete, *e.g.* bees, wasps, ants.

Class 5. **Arachnida** (a-rak-ni-da) : No antennae, legs 4 pairs *e.g.* scorpion, spider, mite, tick.

TEST QUESTIONS

1. Discuss the characteristics of the phylum Arthropoda. Name its classes and show how they differ from each other. Give a few important examples of each.

2. Give an account of the economic importance of insects.

3. Assign to the following animals their rightful place in the animal kingdom. Also write a short note on each :—

Crab, Honey-bee, Grasshopper, Centipede, Scorpion, Wasp, Spider, Prawn.

4. Show the differences between the following :—

(*a*) Butterfly and Moth. (*b*) Dragon-fly and Damsel-fly.
(*c*) Beetle and Bug. (*d*) *Culex* and *Anopheles*.
(*e*) Centipede and Millipede. (*f*) Tick and Mite.
(*g*) Spider and Insect.

5. Give the names of the following :—

(*a*) Two poisonous Arthropoda. (*b*) Three parasitic Insects.
(*c*) Two Aquatic Insects. (*d*) Four Social Insects.
(*e*) Two Singing Insects. (*f*) Four Disease Carriers.
(*g*) Five useful and five harmful Insects. (*h*) Two Wingless Insects.

CHAPTER 34

Phylum Mollusca

(The Soft Animals)

I. Characteristics

The phylum Mollusca includes the mussels, snails, slugs, cuttle-fishes, etc. The mollusks show the following characters—

1. They have a soft, variously shaped, usually unsegmented **body.**
2. The symmetry is fundamentally bilateral but in one class (Gastropoda) it has been lost due to the twisting of the visceral mass.
3. The body develops from three germ layers, hence triploblastic.
4. The body is typically differentiated into three regions : an anterior **head**, a dorsal **visceral mass** and a ventral **foot**.
5. The visceral mass is covered by a thin glandular fold, the **mantle**, which usually secretes a calcareous **shell** outside it for the protection of the animal. In some cases, however, the shell may be internal or even absent.
6. The space between the visceral mass and mantle is called the **mantle-cavity**. This cavity contains the anus and the excretory and genital apertures.
7. Respiration is usually carried on by gills called the **ctenidia.**
8. Some have lungs instead of or in addition to ctenidia. The digestive system is complete.
9. Circulatery system is open, comprising a heart, a few arteries, sinuses and blood with respiratory pigment.
10. Coelom is reduced to cavities in the pericardium, kidneys and gonads.
11. Excretery system includes sac-like kidneys.
12. Nervous system includes paired ganglia connected by commissures and connectives.
13. The animals may be unisexual or bisexual and the gonads have gonoducts.
14. Development may be direct or with a larval stage.
15. The mollusks are widely distributed all over the world in marine, fresh water and terrestrial habitats, though most abundant in the sea.
16. They are typically sluggish animals.

II. Classification

The phylum Mollusca is divided into five classes, of which the more important are **Pelecypoda, Gastropoda** and **Cephalopoda.**

Class 1. Pelecypoda (Lamellibranchiata or **Bivalvia).** It includes the mussels. The body is symmetrical, laterally-compressed and enclosed in a bilobed mantle. The latter secretes a shell of two valves which are movably hinged above. The foot is hatchet-shaped and is used for burrowing and creeping. There is no head. Respiration occurs by gills which are lamellar in nature. The animals may be unisexual or bisexual. They are found both in the sea and fresh water.

Fresh-water Mussel or **Clam** (Fig. 34.1). The fresh-water mussel or clam (*Anodonta*) lives in ponds, streams and rivers, partly burried in sand or mud or wedged between rocks. It feeds on organic particles and micro-organisms like diatoms and protozoans. A current of water enters and leaves the mantle cavity through the inhalent and exhalent siphons situated at the hind end. The current carries oxygen and food into and eliminates carbon dioxide and faeces from the mantle cavity.

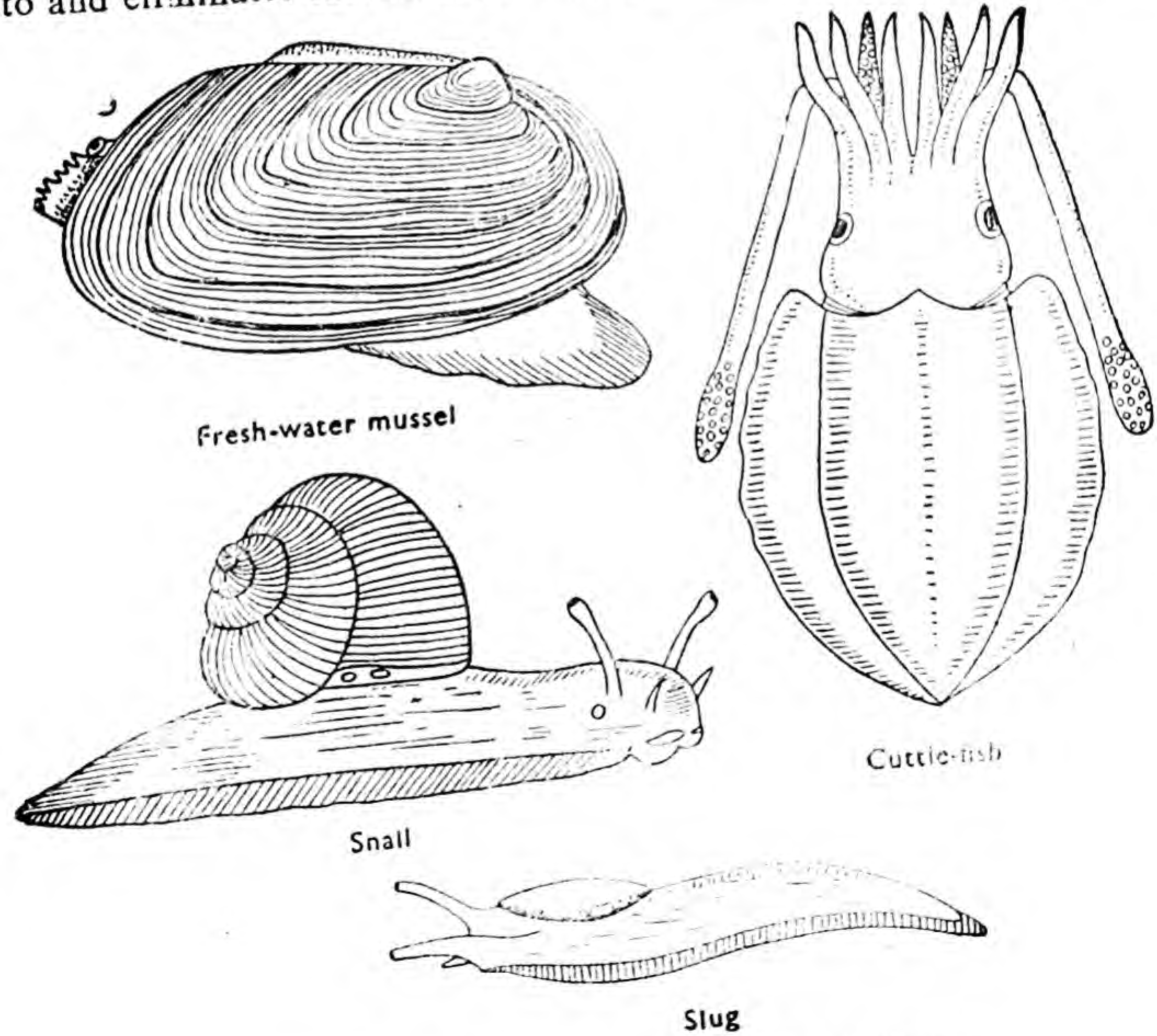


Fig. 34.1. Representatives of phylum Mollusca

The sluggish mussel has a very interesting mode of dispersal. The larvae attach themselves to the skin and gills of fishes on which they live as parasites till they develop into small mussels. The fishes travel to far off places where the young mussels drop off.

Class 2. Gastropoda. It includes the snails and slugs. The body is asymmetrical and spirally coiled. It is enclosed in similarly coiled shell which consists of one piece only. The foot is large and flat and is used for creeping. There is a distinct head with eyes and tentacles. Respiration occurs by gills or mantle-cavity or both. The animals may be unisexual or bisexual. They live in the sea, in fresh water and on land.

Apple Snail (Fig. 34.1). The apple snail (*Pila*) is a fresh-water mollusk, very common in the ponds, streams, lakes and paddy-fields. It has a spirally coiled shell in which it can completely withdraw itself at the time of danger. Even the aperture of the shell can be closed with an operculum borne on the foot. The head bears two pairs of tentacles and a pair of stalked eyes. All apertures (anal, genital and pulmonary) open into the mantle cavity. The movement of the snail is very slow and proverbial, "snail's speed." It is due to the fact that it glides, on a layer of mucus secreted by a gland at the anterior end of the foot. It feeds on small aquatic plants. It can stay out of water as it has a pulmonary sac for breathing air in addition to a gill for breathing in water. Pila is unisexual. Development is direct.

Slug (Fig. 34.1). The slug (*Limax*) is a terrestrial mollusk found almost all over the world. It is naked, the shell being reduced and internal. It, consequently, lives in moist and shady places to save itself from drying up. The head bears two pairs of tentacles : short anterior of tactile function and long posterior bearing eyes at the tips. Anal, genital and pulmonary apertures open directly to the exterior. Its mantle cavity is modified to act as a lung for breathing air. It lacks gills. It is a sluggish creature, creeping very slowly by means of its foot on a self-secreted tract of mucus. It is nocturnal and herbivorous. It is hermaphrodite and oviparous. Development is direct.

Class 3. Cephalopoda. It includes the cuttle-fishes. The body is usually symmetrical. The shell may be external, internal or absent. The foot is modified partly into eight or ten prehensile tentacles or arms for capturing prey and partly into a muscular funnel or siphon. There is a large head with prominent eyes. Respiration occurs by gills. The animals are unisexual. They are exclusively marine.

Cuttle-fish (Fig. 34.1). The cuttle-fish (*sepia*) is a symmetrical, actively-swimming, marine mollusk. Its body is differentiated into a large head, a very small neck and a long trunk. The head bears laterally a pair of large eyes and anteriorly the mouth surrounded by five pairs of arms. The arms of the fourth pair are longer, slender and are called **tentacles.** They bear suckers on the swollen extremities. The remaining arms are shorter, stouter and bear suckers on the whole

of their inner surface. The suckers act as organs of attachment. The trunk is oval and bordered laterally by muscular folds, the **fins**. It is strengthened by an internal calcareous shell.

The cuttle-fish is carnivorous. It swims in a characteristic manner. It forcibly expels water from the mantle cavity through the funnel in one direction and is itself pushed in the opposite direction. It possesses a peculiar ink gland for defence. When chased by an enemy, it discharges into water dark clouds of ink which enable it to escape.

III. Economic Importance

Mollusks are of great economic importance. Oysters, mussels, squids, snails, slugs, etc. are edible. Many forms provide food for useful fishes and mammals. Oyster shells are used for supplying lime to poultry. Buttons are cut from the shell of fresh-water mussels. The pearl oysters provide valuable pearls. Cuttle-fishes yield sepia pigment from ink glands. Mollusk shells are used on roads. The shells with bright colourful patterns and curious shapes form decorative pieces. Many mollusks act as scavengers to keep the water clean.

Some mollusks are harmful also. Slugs damage tender vegetation in gardens and green-houses. Snails serve as intermediate hosts for certain harmful parasitic flat worms. *Teredo*, the ship-worm, destroys the ships by burrowing in the wood.

IV. Summary

Phylum **Mulluska** (mol-us-ka) : Soft animals usually with shell.

Class 1. **Pelecypoda** (pe-le-sip-o-da) : Shell of two valves, foot axe-like, e.g. mussel and oyster.

Class 2. **Gastropoda** (gas-trop-o-da) : Shell spiral, foot flat, *e.g.* snail, slug.

3. **Cephalopoda** (sef-a-lop-o-da) : Shell internal or coiled like watch-spring, *e.g.* cuttle-fish.

TEST QUESTIONS

1. Give important characters and classification of the phylum Mollusca.

2. Give the systematic position of and write a brief ecological note on fresh-water mussel, pearl oyster, snail, slug and cuttle-fish.

CHAPTER 35

Phylum Echinodermata

(The Spiny-skinned Animals)

I. Characteristics

The phylum Echinodermata includes the star-fishes, sea-urchins, brittle-stars, sea-cucumbers sea-lilies, etc. The echinoderms show the following characters—

1. They have radial symmetry.

2. They are triploblastic and unsegmented.

3. The body is variously shaped and is always without a head.

4. Many organs are ciliated.

5. The body-wall usually contains an endoskeleton of calcareous plates which bear protruding spines.

6. Coleom is large and lined with ciliated peritoneum. A part of the larval coelom produces a peculier system, the **water vascular system,** which includes the structures called the **tube-feet**. This system helps in locomotion, capturing food and respiration.

7. The digestive system is usually complete.

8. Circulatory system is reduced.

9. Nervous system consists of a nerve-ring round the mouth and radial nerves.

10. The sexes are separate.

11. There is a free-swimming ciliated larva with bilateral symmetry.

12 All echinoderms are marine.

II. Classification

The phylum Echinodermata is divided into five classes : **Asteroidea, Echinoidea, Ophiuroidea, Holothuroidea and Crinoidea.**

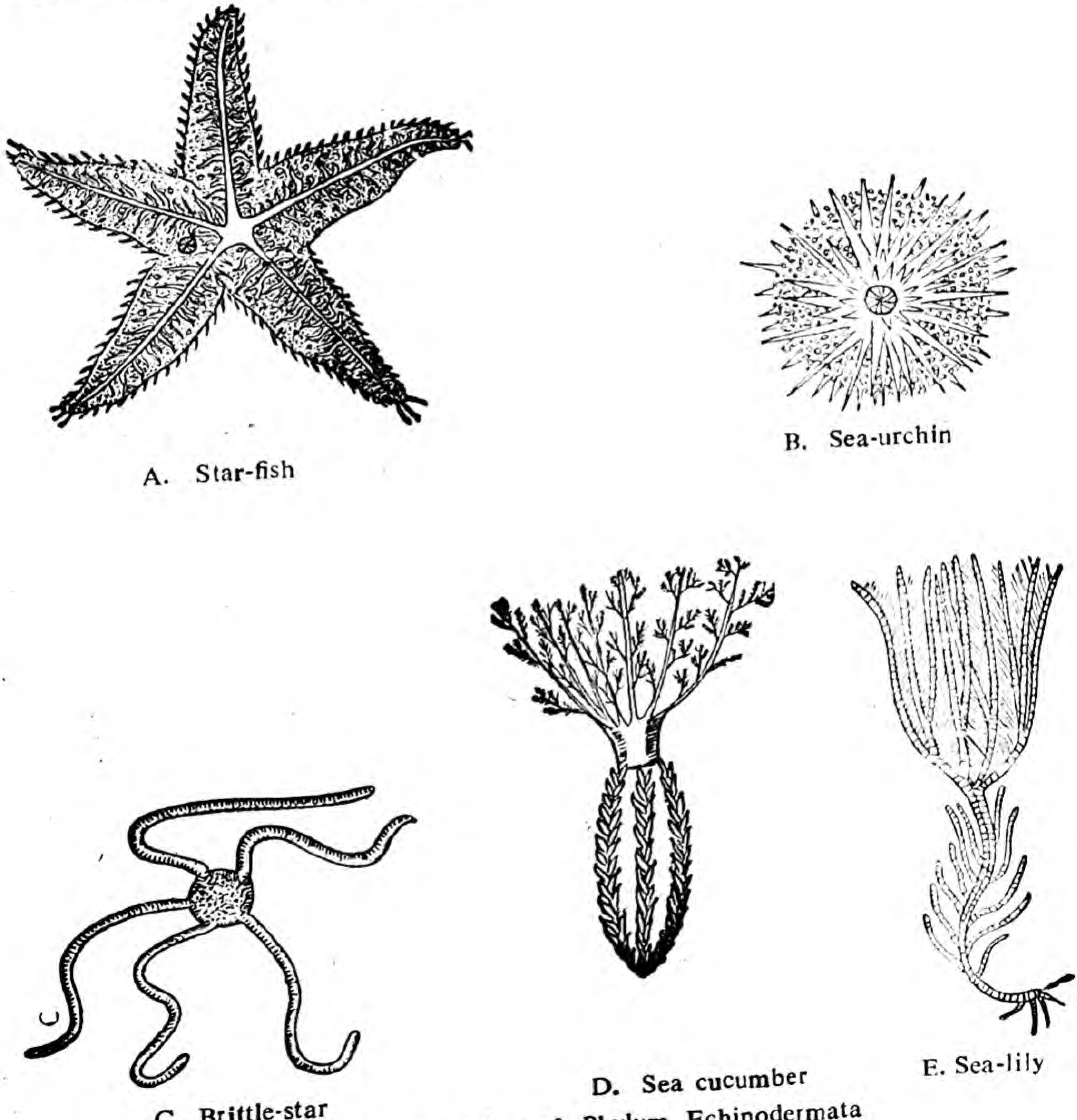
Class 1. Asteroidea. It includes the star-fishes or sea-stars (Fig. 35.1-A). The body is star-shaped. The arms are not sharply marked off from the central disc. The spines are short.

Class 2. Echinoidea. It includes the sea-urchins (35.1-B). The body is globular or disc-like. The spines, if present, are very long.

Class 3. Ophiuroidea. It includes the brittle-stars (Fig. 35.1-C). The arms are distinctly marked off from the central disc. The anus is absent.

Class 4. Holothuroidea. It includes the sea-cucumbers (Fig. 35.1-D). The body is long and cylindrical. There are no spines. The endoskeleton consists of minute spicules. Mouth is surrounded by tentacles.

Class 5. Crinoidea. It incudes the sea-lilies or feather stars (Fig. 35.1-E). The branching arms arise from a cup-like calyx which is fixed by a stalk. The spines are absent.



A. Star-fish B. Sea-urchin

C. Brittle-star D. Sea cucumber E. Sea-lily

Fig. 35.1. Representatives of Phylum Echinodermata

III. Economic Importance

Echinoderms have very little economic importance. Eggs of star-fishes and sea-urchins are eaten in certain regions. Dry sea-cucumbers are used in soup. Because of their high percentage of calcium and nitrogen, the skeletons of echinoderms are dried and used as fertilizer. The eggs of star-fishes and sea-urchins are also used in experimental researches. Star-fishes are harmful also as they destroy oyster-beds.

TEST QUESTION

1. Describe the characteristic features of echinoderms. Name their main groups, giving example of each. Discuss the economic importance of echinoderms.

CHAPTER 36

Phylum Chordata

(The Chordates)

The chordates mark the climax of the animal kingdom. They include the larger and more familiar animals including man. They exhibit diversity of habitat, form and structure to an amazing degree. Only the Arthropoda among the non-chordates rival them in this regard. Many chordates are of great economic importance to mankind. Because of all these factors, the phylum Chordata is regarded as the most important group of animals.

I. Characteristics

The chordates possess the following diagnostic features (Fig. 36.1).

1. Notochord. The notochord is a supporting rod lying between the alimentary canal and the central nervous system. The phylum derives its name from this structure. It is present in all chordates at some stage of life. In lower forms, it persists throughout life while in higher ones, it is replaced, wholly or partially, in the adult by a **back-bone or vertebral column**. There is no notochord in the non-chordates.

2. Dorsal Hollow Central Nervous System. The central nervous system in chordates is a hollow tube located against the dorsal body-wall in contrast to the solid and ventral nerve-cord of non-chordates. The dorsal hollow cord persists throughout life in almost all the chordates except a few forms where it degenerates in the adult.

3. Gill-slits. The gill-slits are perforations in the wall of the pharynx. They occur in all the chordates at some stage of life. They are retained throughout life by the lower forms, like protochordates, fishes and some amphibians, but developed only in the larval or embryonic stages in the higher forms, like some amphibians, reptiles, birds and mammals. There are no gill-slits in the non-chordates.

4. Tail. The tail, which is the part of the body behind the anus, is developed in almost all the chordates. It is very flexible and muscular and contains no viscera. In the aquatic forms it is the chief propulsive organ while in the terrestrial forms it takes various shapes and functions or may be reduced in the adult. The tail is absent in the non-chordates.

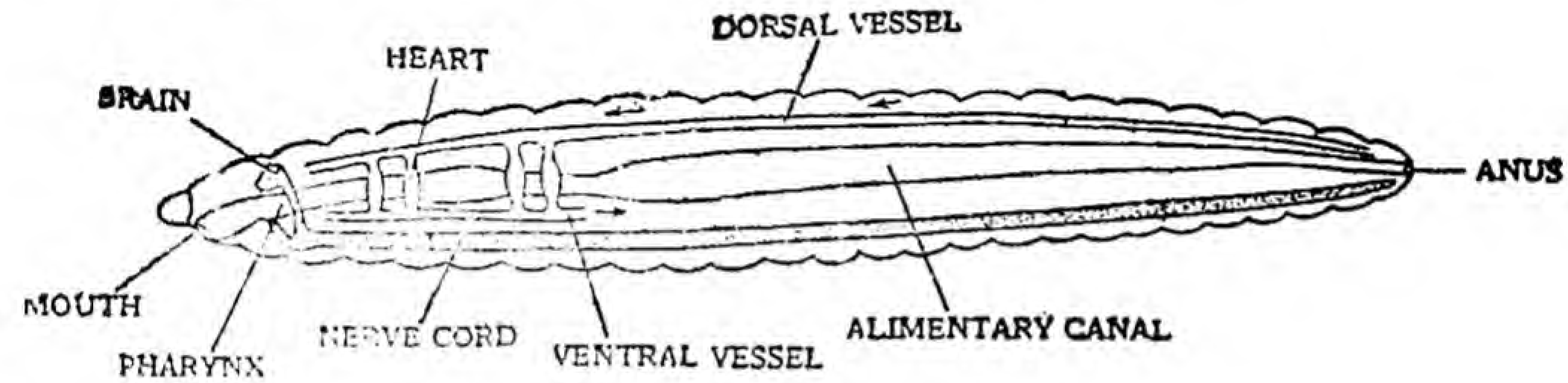
5. Closed Vascular System. The blood flows in a closed system of arteries, capillaries and veins. It is kept circulating by a muscular heart which is ventral and anterior in position. The blood moves backwards in the dorsal and forwards in the ventral vessel. This is just the reverse

of the condition prevalent among the non-chordates. In the chordates the blood carries haemoglobin in the red blood-corpuscles. The respiratory pigment, if present, is dissolved in the plasma in the non-chordates.

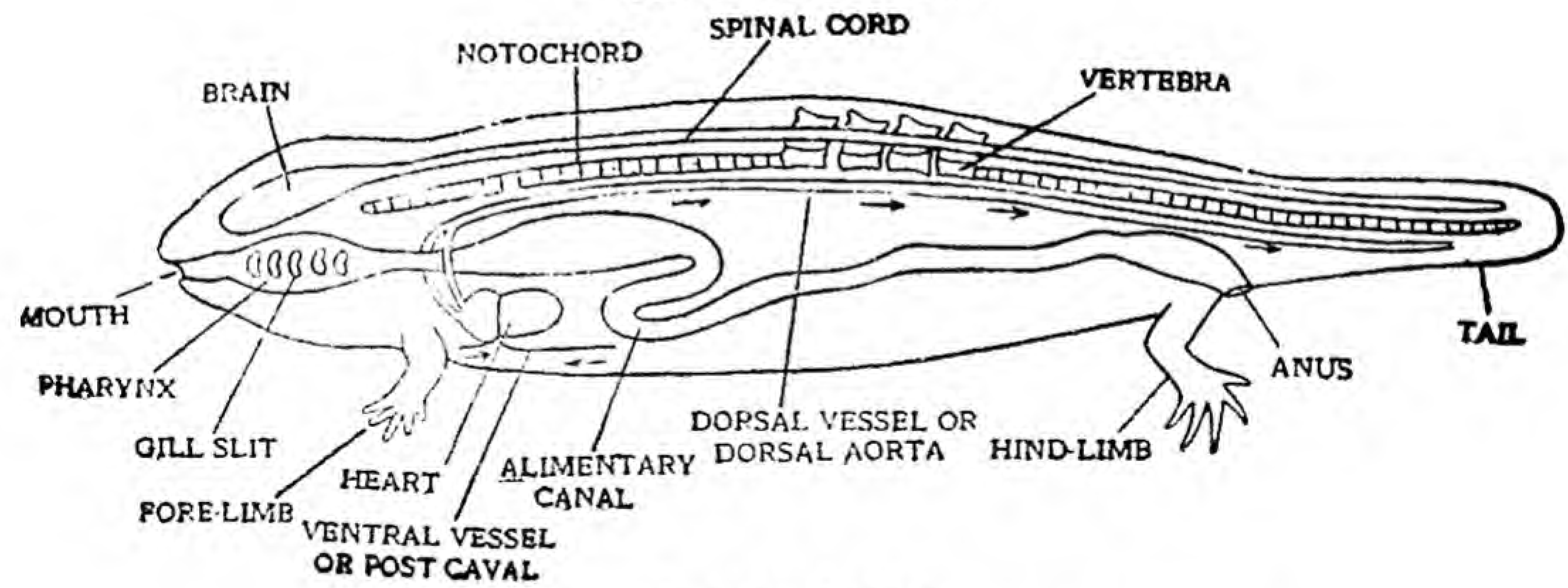
6. **Endoskeleton.** The main supporting frame-work of the chordates, when present, is usually internal to the muscles and is called the **endoskeleton.** It consists of cartilage or bone and contains living cells. On the other hand, the supporting framework in the non-chordates, if present, is usually external to the muscles and is called the **exoskeleton.** It is secreted by the epidermis and does not contain living cells.

7. **Appendages.** The appendages, if present, occur in not more than two pairs (fins or limbs) in the chordates and in several pairs in the non-chordates.

8. **Metamerism.** The chordates show segmentation which frequently tends to be masked externally. The non-chordates usually lack segmentation except the annelids and arthropods in which segmentation is of different type.



A typical non-chordate



A typical chordate.

Fig. 36.1. Figures showing fundamental difference between a chordate and a non-chordate

The chordates are further characterized by the following features which they share with many other phyla.

They are triploblastic, have organ grade of construction, show bilateral symmetry, possess well-developed coelom, have a complete digestive tract, and usually develop distinct head with sense organs at the anterior end of the body.

II. Classification

The phylum Chordata is generally split up into four sub-phyla : **Hemichordata, Urochordata, Cephalochordata** and **Vertebrata.**

Sub-phylum 1. Hemichordata*. In the Hemichordata the body is divisible into three parts : **proboscis, collar** and **trunk**. The structure regarded as notochord is a very short hollow diverticulum from the alimentary canal and is confined only to the base of the proboscis. The central nervous system is not truly tubular as it contains only irregular spaces. It has a ventral nerve-cord in addition to the dorsal one. The gill-slits are usually present. The direction of the blood flow in the dorsal and ventral vessels is of the non-chordate type. The tail is absent.

The **acorn worm** (Fig. 36.2.) is a common hemichordate. It is a soft worm-like creature found in shallow waters of almost all the seas.

Sub-phylum. 2. Urochordata. The larva and the adult of the Urochordata are widely different. The larva called **"tadpole"** resembles a typical chordate in having a tail, dorsal hollow central nervous system, gill-slits, and a distinct notochord. The notochord is, however, confined to the tail only. After a brief free swimming life, the larva fixes itself to some object, its tail is absorbed, notochord disappears and the central nervous system is reduced to a single ganglion. The sedentary adult, which is left only with a single chordate feature, namely, the gill-slits, develops a leathery covering, the **test** or **tunic**, round it. This change from a more chordate-like larva into a degenerate adult is called **retrogressive metamorphosis.**

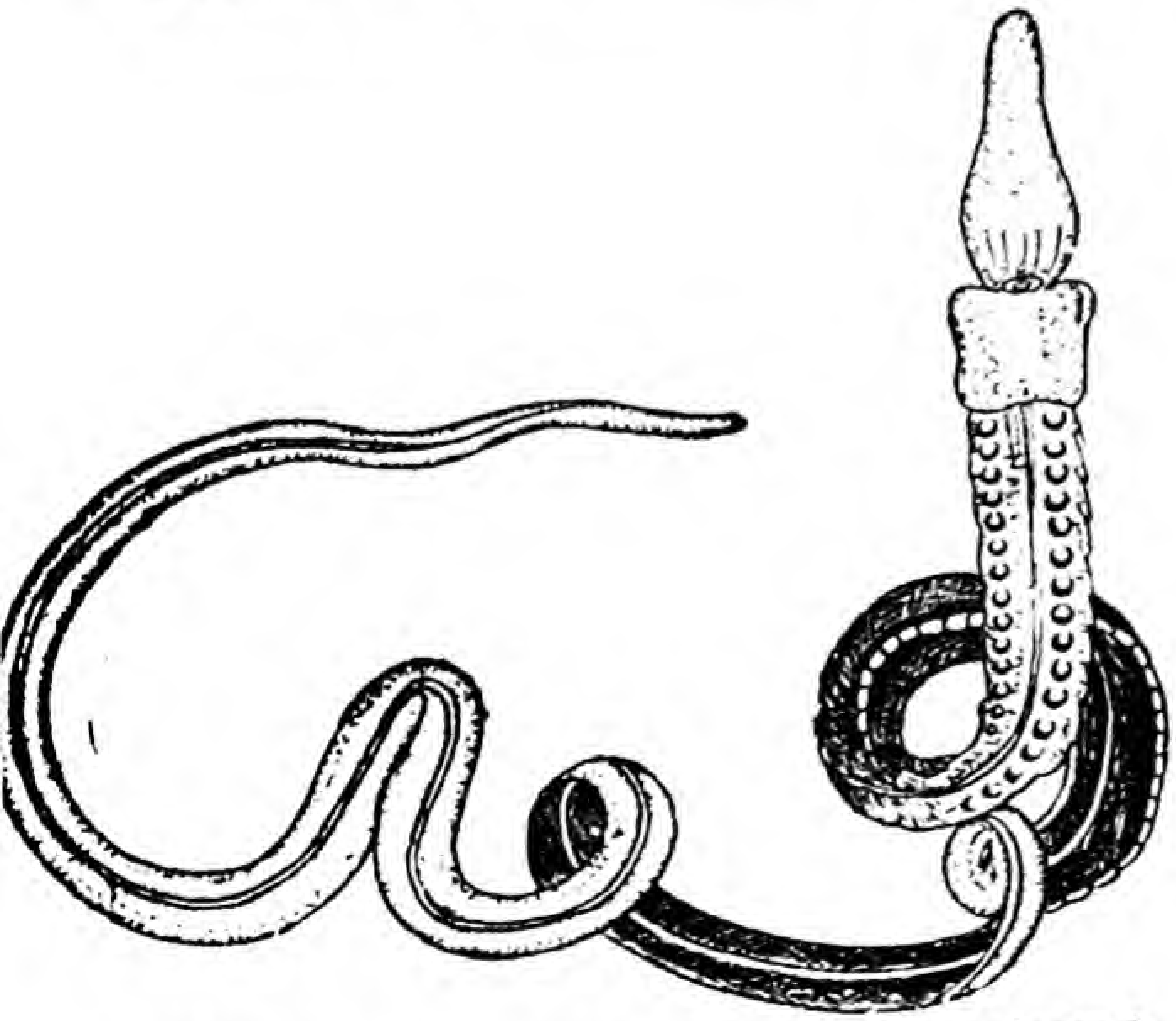


Fig. 36.2. The acorn worm (*Balanoglossus*)

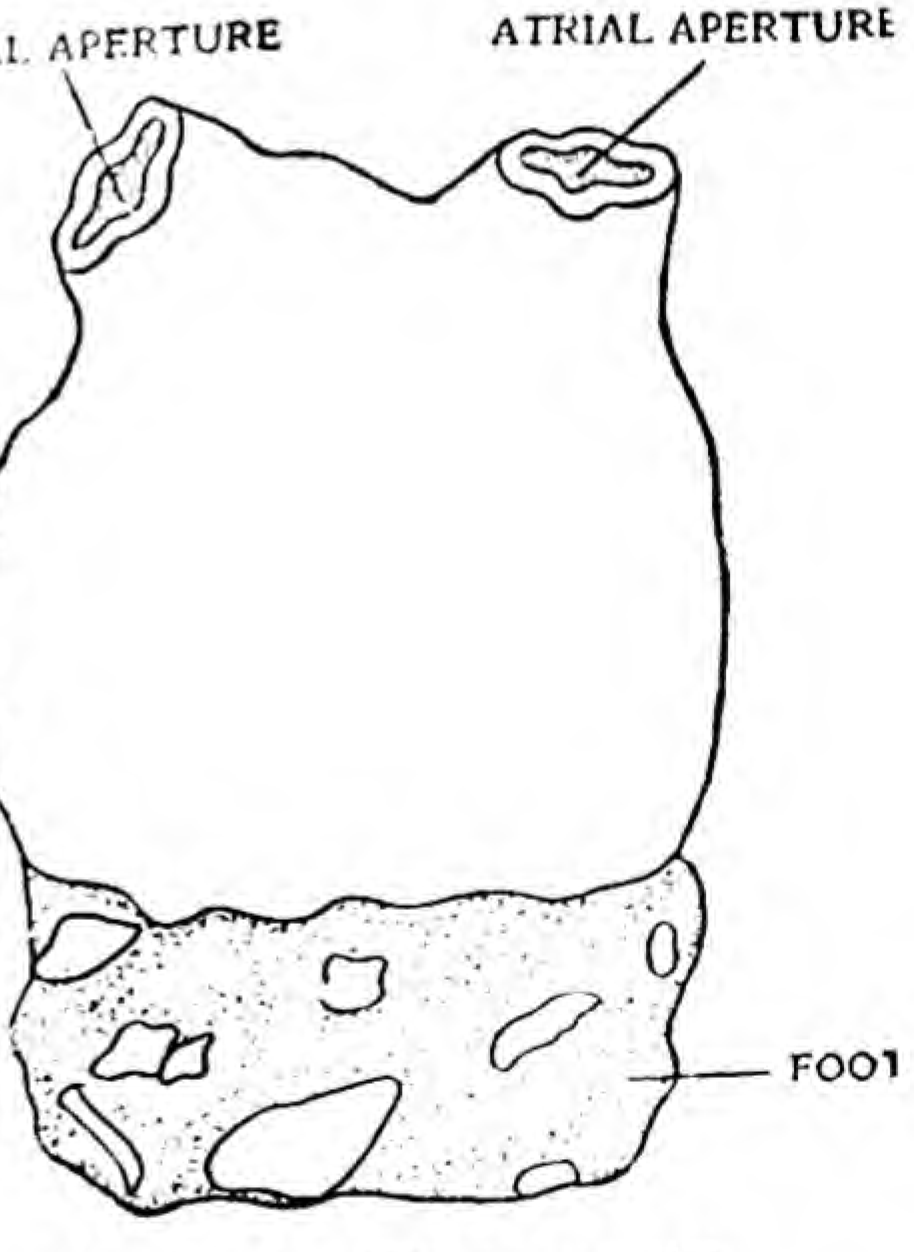


Fig 36.3 The sea-squirt (*Herdmania pallida*)

*There is now a tendency to exclude the Hemichordata from the Chordata as their chordate affinities are very doubtful.

The **sea-squirt** (Fig. 36.3) is a common urochordate. It inhabits the rocky beds in the coastal waters of the Indian seas.

Sub-phylum 3. Cephalochordata. The Cephalochordata have an elongated, laterally-compressed fish-like body but without paired fins and head. Both the notochord and the nerve-cord are well developed, extend along the entire body and persist throughout life. There are several gill-slits in the wall of the pharynx. Tail is retained in the adult stage.

The **lancelet** (Fig. 36.4) is the common cephalochordate. It lives near the sea-coast, partly burried in sand.

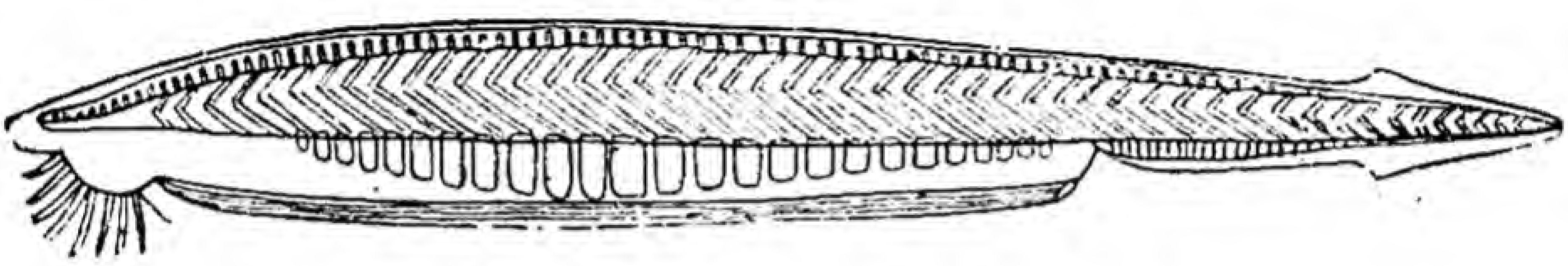


Fig. 36.4. The lancelet (*Amphioxus*)

Sub-phylum 4. Vertebrata (Craniata). The vertebrates are the typical chordates. They have the following features in addition to the universal chordate characters listed earlier :—

1. The notochord is partly or completely replaced in the adult by a segmented vertebral column (hence Vertebrata).

2. The anterior part of the dorsal nerve-cord is differentiated into the brain, the rest forming the spinal cord.

3. The front end of the body is transformed into head to lodge the brain and the sense organs.

4. The head develops skull to provide cranium for protection of the brain (hence Craniata) and partial or complete capsules for the sense organs.

5. There is a true muscular heart with valves and at least two chambers, an auricle and a ventricle.

6. One or two portal systems of veins have been developed.

7. The pharynx is comparatively small and the gill-slits are fewer in number.

8. The skin consists of two regions : outer epidermis of many cellular layers and the inner dermis of connective tissue.

9. The organs for the excretion of nitrogenous wastes are kidneys.

10. There is a definite system of endocrine glands.

11. The sexes are separate ; gonads are reduced to a single pair in the adult ; gonoducts are almost invariably present for the discharge of the sex cells.

12. Asexual reproduction and colony formation are entirely unknown.

The sub-phylum Vertebrata is divided into two super-classes ; **Agnatha** and **Gnathostomata**.

Super-Class 1. Agnatha. This super-class includes the vertebrates which lack jaws. It has a single class the **Cyclostomata.**

Class Cyclostomata. The cyclostomes have an eel-like body with smooth, scaleless, slimy skin. The rounded, suctorial, jawless mouth remains permanently open. The paired fins and their girdles are absent. The median fins are present but lack true fin-rays. The notochord is persistent. The vertebrae are rudimentary. Skeleton is cartilaginous. The cranium is incomplete. The olfactory organ is unpaired. The internal ear has only one or two semicircular canals, the horizontal canal being absent. The pineal body is eye-like and sensitive to light. The cyclostomes live both in fresh and salt water.

Lamprey (Fig. 36.5). The lamprey is a common cyclostome. It lives in the sea but ascends the rivers to spawn in spring. It has two dorsal fins, a tail fin and seven pairs of gill-slits. The animal has a

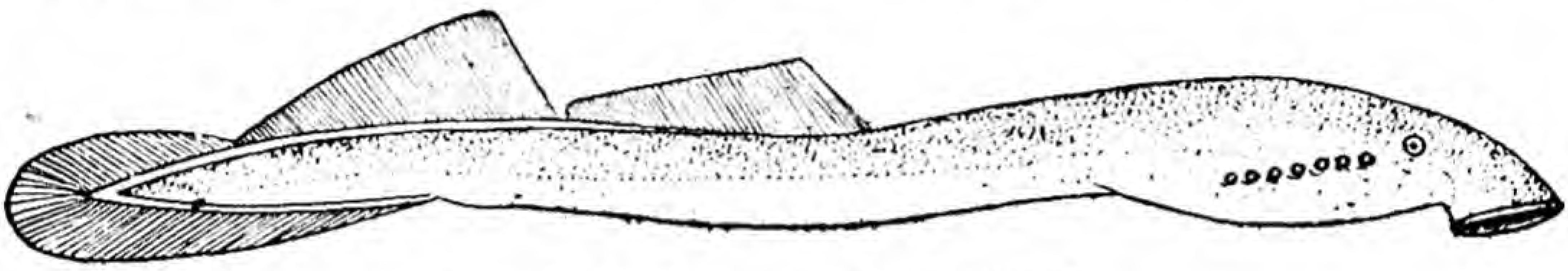


Fig. 36.5. Lamprey (*Petromyzon*)

peculiar way of feeding. It attaches itself to the body of a larger fish by its suctorial mouth, makes punctures in the body of the prey with the teeth present on the tongue and sucks the blood and small pieces of flesh. The prey dies afterwards.

Super-class 2. Gnathostomata. The super-class includes the vertebrates that possess jaws. It comprises six classes : **Chondrichthyes, Osteichthyes, Amphibia, Reptilia, Aves** and **Mammalia.** Of these, the first two classes are often combined together in the group **Pisces** and the remaining four are assigned to a common group **tetrapoda.**

TABLE 19.

Pisces	Tetropada
1. These are all cold-blooded animals.	1. These include both cold and warm-blooded forms.
2. These are all aquatic.	2. These are typically terrestrial though some have become aquatic secondarily.
3. These breath by gills throughout life.	3. These breath by lungs. A few breath by gills in the larval stage or even throughout life.
4. Their paired appendages are fins.	4 Their paired appendages are pentadacyle-limbs.
5. Their heart is 2 chambered.	5. Their heart is 3 or 4 chambered.
6. These have 10 pairs of cranial nerves.	6. These have 10 or 12 pairs of cranial nerves.
7. These lack internal nares.	7. These possess internal nares.
8. These have lateral line sense organs.	8. These lack lateral line sense organs.
9. These have only internal ear.	9. These have middle and external ears in addition to internal ear.

CLASS 1. CHONDRICHTHYES (ELASMOBRANCHII)

All Chondrichthyes are marine. They are cold-blooded vertebrates. The skin is tough and covered with an exoskeleton of **placoid scales,** which develop partly from the mesoderm and partly from the ectoderm. Both median and paired fins are present. They are supported by horny fin-rays. The pelvic fins bear claspers in the males. The tail is heterocercal or asymmetrical. The mouth and external nares are on the ventral side of the head. The internal nares are absent. The pharynx has five to seven pairs of gill-slits which are usually uncovered. In front of the gill-slits there is often a slit, the **spiracle**. There is no air-bladder. The notochord is only partially replaced by vertebrae. The endoskeleton is cartilaginous. The digestive and urinogential systems have a common outlet, the cloacal aperture. Sharks and rays are examples.

Indian Shark (Fig. 36.6). The scientific name of the common Indian Shark is *Scoliodon*,

(*i*) **Habitat**. The Indian shark is found along the coasts of India.

(*ii*) **Habits**. It is carnivorous in diet, feeding on crabs, lobsters and fishes. It is a swift swimmer. It is **viviparous**, *i.e.* it delivers living **young.** It is eaten by poor people.

(*iii*) **External Characters.** A full-grown specimen is about 60 centimetres long. It is grey above and white below. It has a long spindle-shaped body tapering at both the ends. The body is divisible into three parts : **head, trunk** and **tail**. There is, however, demarcation between these regions. The head is dorso-ventrally compressed and is produced in front into a thin wedge-shaped **snout**. It bears a wide crescentic **mouth** and a pair of oblique **external nares** on the ventral side and a pair of rounded **eyes** laterally. The trunk and the tail are flattened from side to side. The trunk bears 5 vertical **gill-slits** on each side just behind the head, fins (paired as well as unpaired) and an elongated **cloacal aperture** on the ventral side. The tail is turned upwards and is described as **heterocercal**.

There are four median fins. Of these, two are on the dorsal side and are known as the **dorsal fins,** one is on the ventral side and is termed the **ventral fin** and one is round the tail and is named as the **caudal** or **tail fin**. The first dorsal fin is triangular in outline and is situated a little in front of the middle of the body. The second dorsal fin is also triangular but is much smaller. It lies near the end of the trunk. The caudal fin is narrow on the upper side and broad on the lower side, where it is divided into two parts by a notch. The ventral fin lies some distance in front of the caudal fin. At the base of the tail there is a shallow **caudal pit** on the dorsal as well as the ventral side.

The paired fins are in two pairs. The fins of the anterior pair are known as the **pectoral fins** and those of posterior pair as the **pelvic**

fins. The pectoral fins are large and triangular. They arise from the ventro-lateral margins of the trunk just behind the gill-slits. The pelvic fins are much smaller than the pectorals. They arise close together from the ventral side. In the male, each pelvic fin bears a copulatory organ, called the **clasper**, along its inner edge.

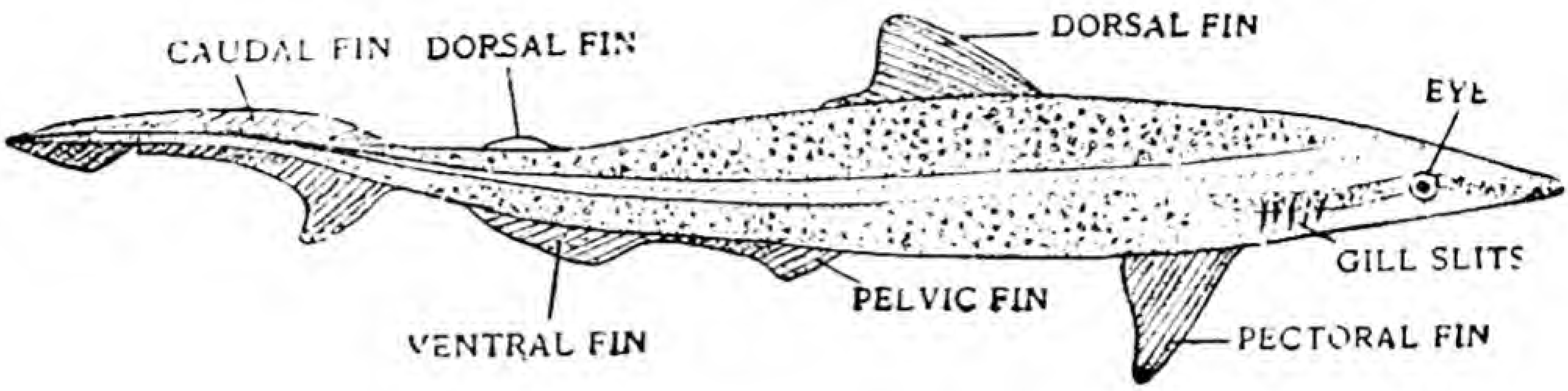


Fig. 36.6. The India Shark (*Scoliodon*)

All the fins are directed backwards. This is helpful to the fish in forward propulsion through water.

There is a faint line on either side of the body. This is called the **lateral line**. It marks the position of underlying special receptor organs for detecting waves and current in water.

Electric Ray (Fig. 36.7). The electric ray (*Torpedo*) is found in the Mediterranean and Red Seas and in the Atlantic, Pacific and Indian

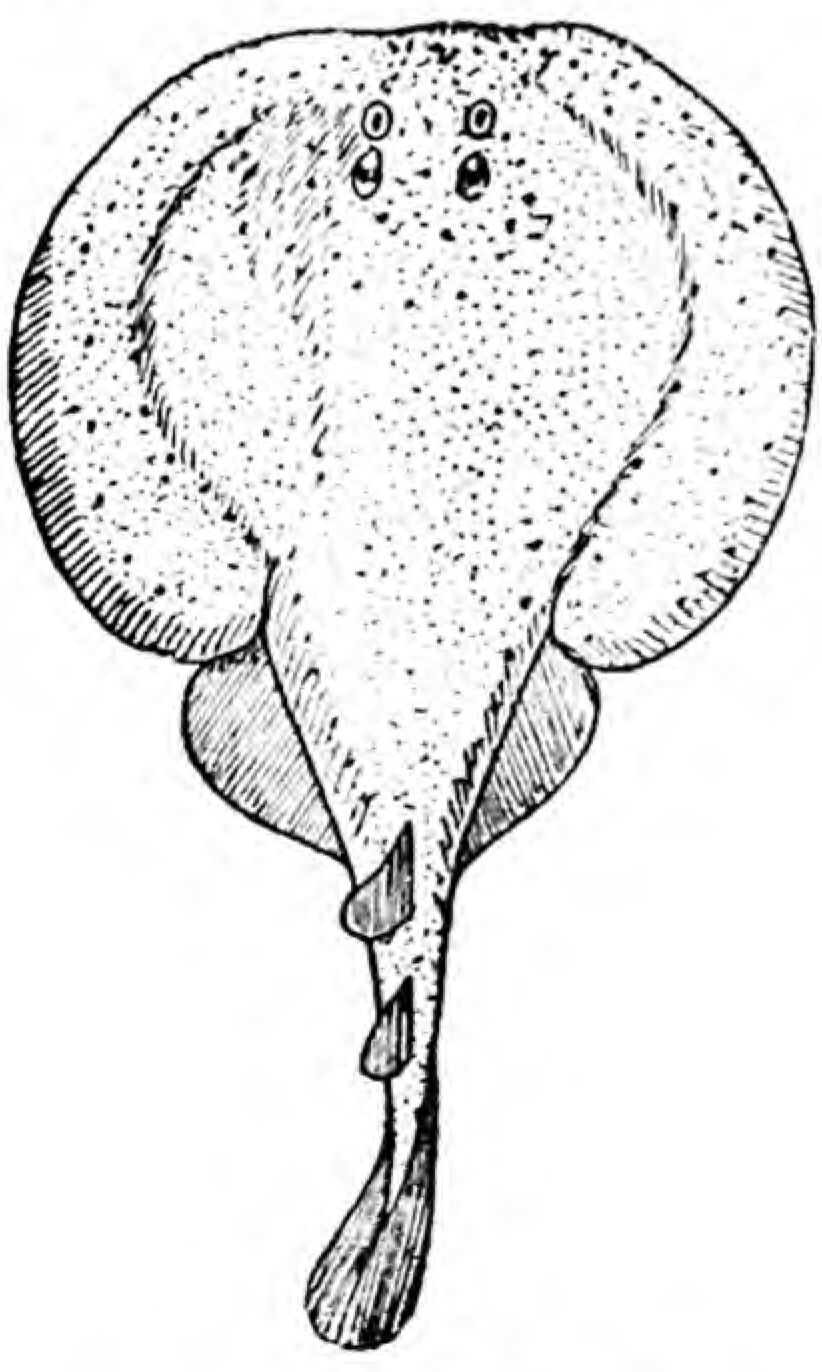


Fig. 36.7. The electric ray (*Torpedo*)

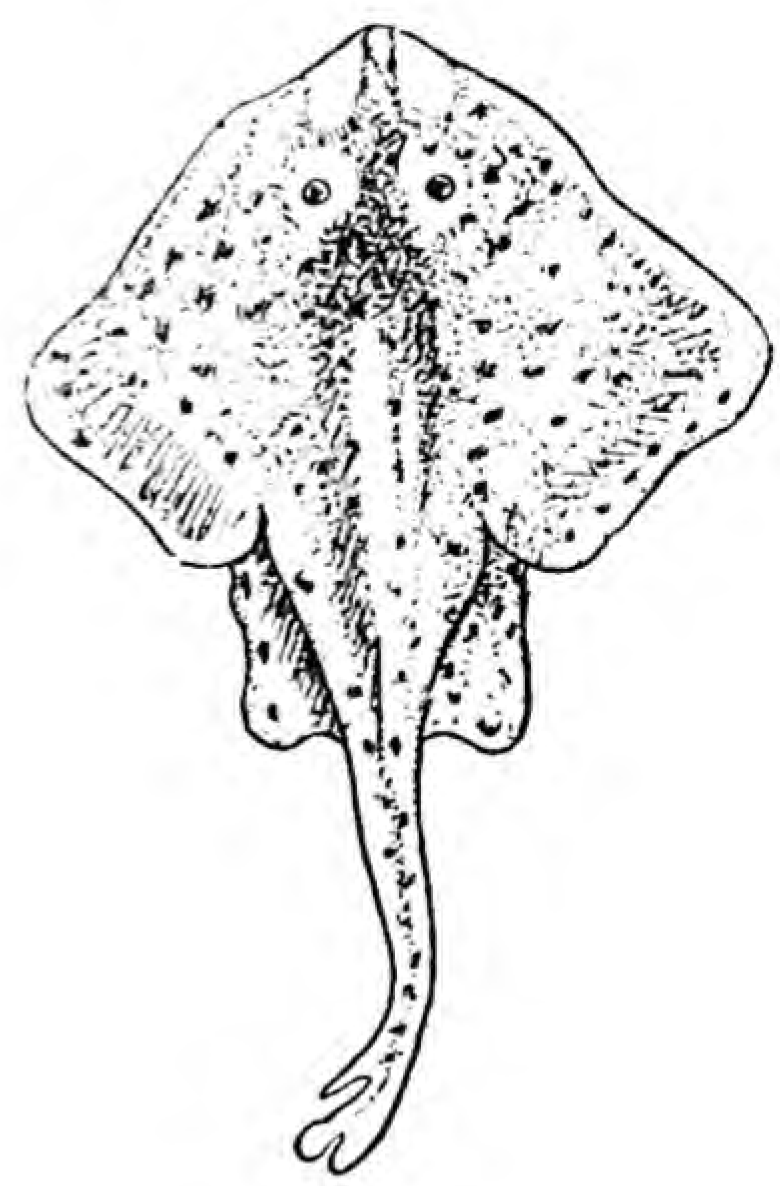


Fig. 36. 8. The sting-ray (*Dasyatus or Trygon*)

Oceans. It leads a sluggish life on the sea-floor. Its body is dorso-ventrally compressed and is nearly circular in outline. The mouth, external nares and gill-slits are on the ventral side. The eyes and spiracles are on the dorsal side. The pectoral fins are very large and are confluent with the sides of the head. The pelvic fins are much shorter and lie at the junction of the trunk and the tail. The tail is short, thick and well-marked off from the trunk. It bears two dorsal fins and a caudal fin.

The fish is carnivorous in diet and feeds on crustaceans, mollusks, and other fishes. It has a pair of large electric organs which give powerful electric shocks to stun or kill the prey and enemies. Larger specimens may disable man. The electric organs consists of modified muscles.

Sting-ray (Fig. 36.8). The sting ray (*Trygon*) inhabits the Mediterranean and the Atlantic, Pacific and Indian oceans. It has a subrhombic body with nares, mouth and gill-slits on the ventral side ; eyes and spiracles on the dorsal side ; and a long whip-like tail sharply marked off from the trunk and bearing a sharp serrated spine in place of the dorsal fin.

CLASS 2. OSTEICHTHYES (TELEOSTOMI)

The Osteicthyes occur both in fresh and salt water. They are also cold-blooded. The skin is delicate and is covered with an exoskeleton of scales which are usually **cycloid** but may be **ctenoid** or **ganoid**. The scales develop entirely from the mesoderm and are bony in nature. Both median and paired fins are present. They are supported by cartilaginous or bony fin-rays. The pelvic fins are without claspers in both the sexes. The tail is **homocercal,** *i.e.* **symmetrical.** The mouth lies at the anterior end of the head. The internal nares are rarely present. The pharynx has only four pairs of gill-slits which are covered by an operculum. There is no spiracle. The air bladder is present. The notochord is almost completely replaced by vertebrae. The endoskeleton is partly or completely bony. The digestive and urinogenital systems have separate outlets.

A few interesting examples of the class are carp, cat-fish, flying fish, climbing perch, sea-horse, flat fish and lung fish.

Carp (Fig. 36.9). The common carp is *Labeo rohita.*

(*i*) **Habitat.** *Labeo rohita* is the fresh-water carp. It is found in all the rivers and streams of Punjab. Its local names are **Rohu** and **Dambra.** It is an excellent food fish.

(*ii*) **Habits.** The fish is carnivorous when young, feeding on crustaceans and insect-larvae. When adult, it changes its diet and becomes herbivorous. It prefers clear water. It breeds in July and August.

(iii) **External Characters.** A full-grown carp is about 90 centimetres long. It is greyish on the back and silvery-white on the sides and belly. The body of the fish is elongated and laterally compressed. It is divisible into three parts : **head, trunk** and **tail**. The head bears the **mouth**, a pair of small thread-like **barbels** on the upper jaw, two pairs of small **external nares** and a pair of prominent eyes. The trunk and the tail are covered with scales. The tail is straight and symmetrical.

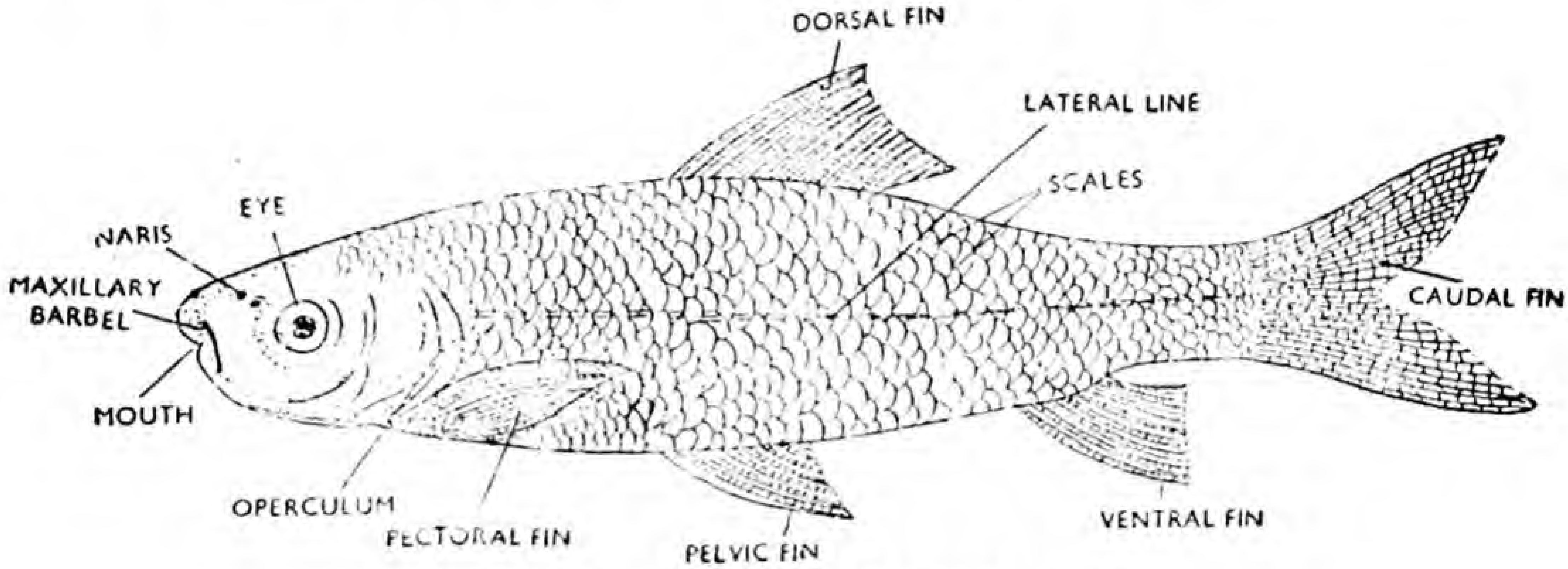


Fig. 36.9. The Carp (*Labeo rohita*)

The fish possesses both median and paired fins. There are three median fins : a large **dorsal fin** on the middle of the back, a smaller **ventral fin** behind the middle of the belly and a deeply-forked symmetrical **caudal fin** at the end of the tail. The paired fins include **pectorals** and **pelvics**. The pectoral fins are larger and triangular. They arise from the ventro-lateral margin of the trunk close to the operculum. The pelvic fins are smaller and arise from the ventral surface of the trunk opposite to the dorsal fin. All the fins are supported by bony fin-rays and all of them are directed backwards.

A lateral line runs along either side of the body. It marks the position of special sense organs meant for the detection of waves and currents in water.

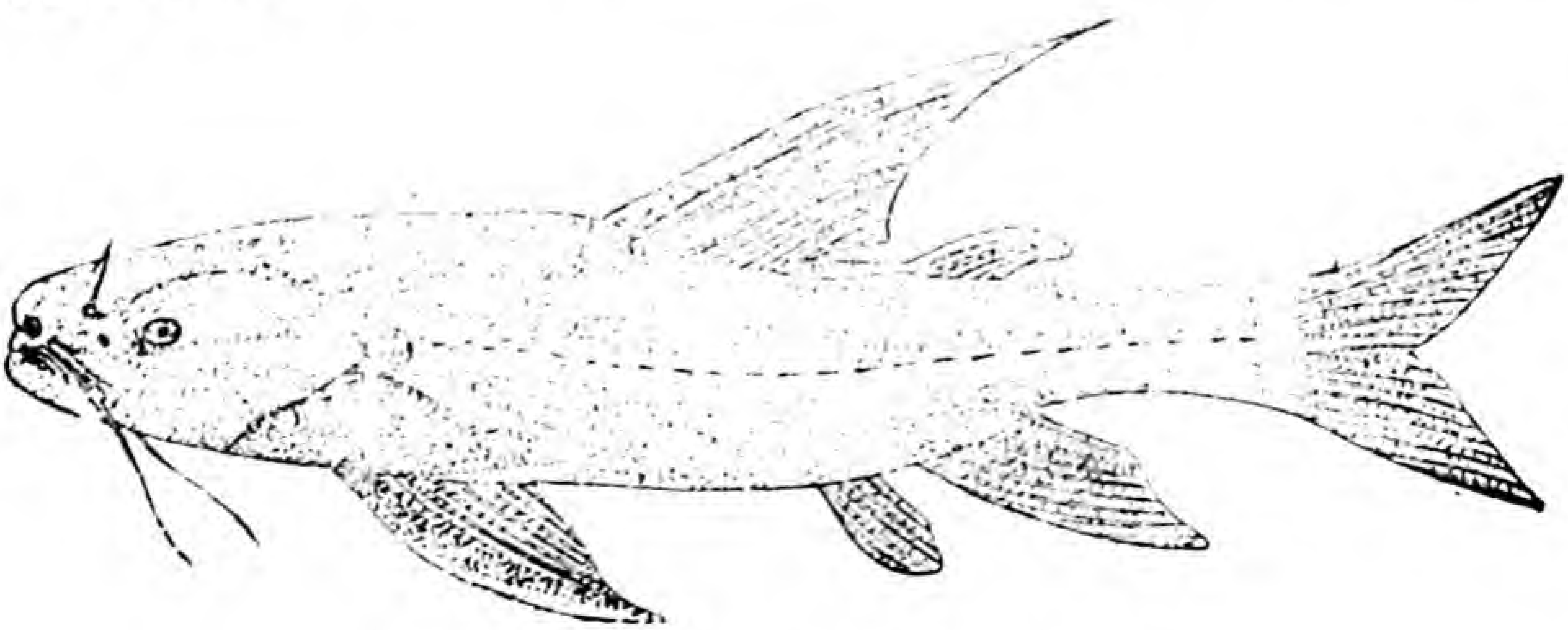


Fig. 36.10. The cat-fish (*Rita rita*)

Cat Fish (Fig. 36.10). The cat-fish (*Rita rita*) is found in the rivers and streams of Punjab. Its local names are **Khagga and Tirkanda.** The body is covered by soft slimy scaleless skin except a few hard bony plates on the depressed head. The head bears three pairs of barbels : **two** pairs on the upper jaw and one pair on the lower jaw. There are two dorsal fins. The posterior dorsal fin lacks fin-rays and is very soft. It is called the **adipose fin**. The anterior dorsal and the pectoral fins are armed with a strong backwardly directed spine each along the anterior border. The fish is carnivorous and prolific breeder. During winter it hides itself under rocks and stones at the bottom. It can cause severe wounds with its spines.

Flying fish. (Fig. 36 11). The flying-fish (*Exocoetus*) inhabits the tropical and sub-tropical seas. It takes leap from water with powerful tail and slowly glides through the air with pectoral fins which are very

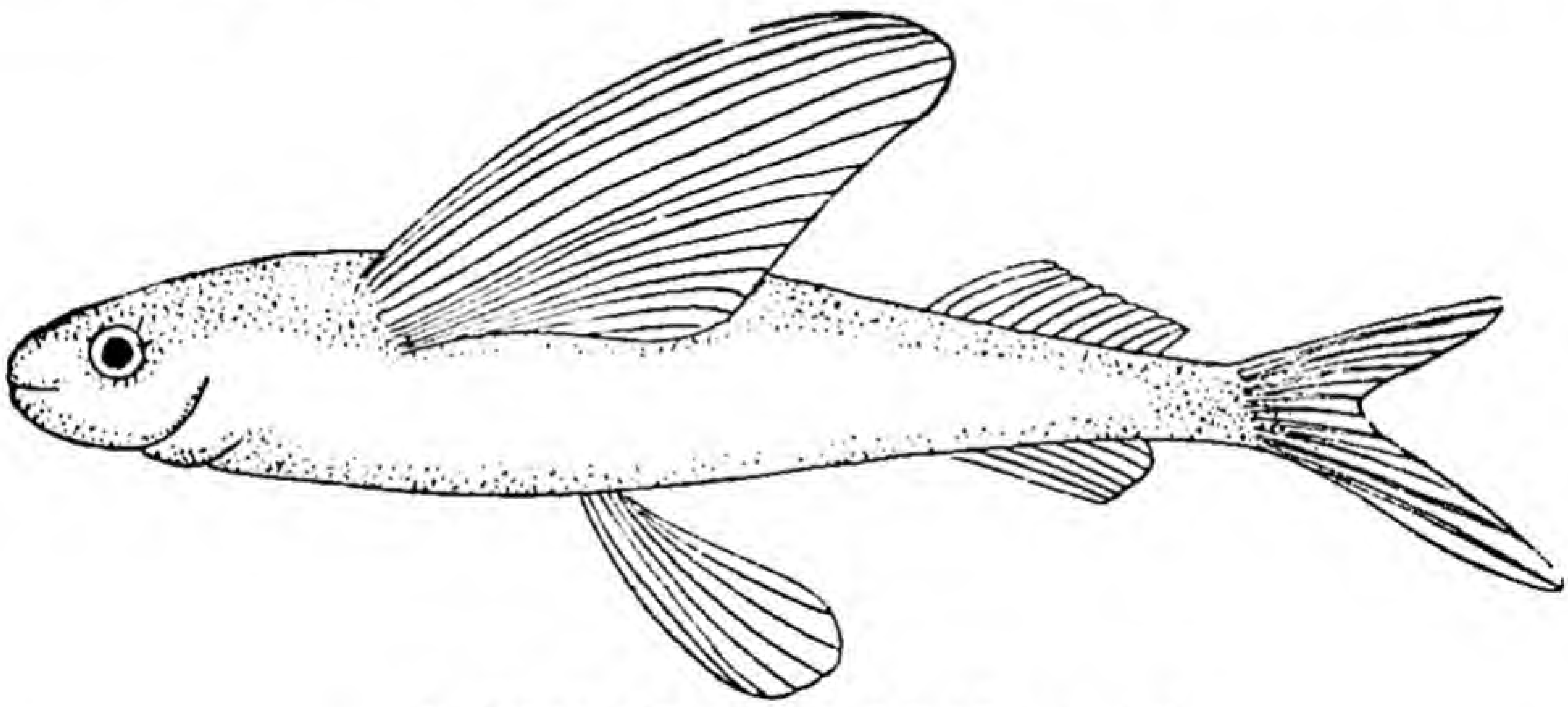


Fig. 36.11. The flying fish (*Exocoetus*)

large for this purpose. The pectoral fins only act as parachute as no force is acquired in the air. The fish takes to flight to escape from enemies. It is carnivorous.

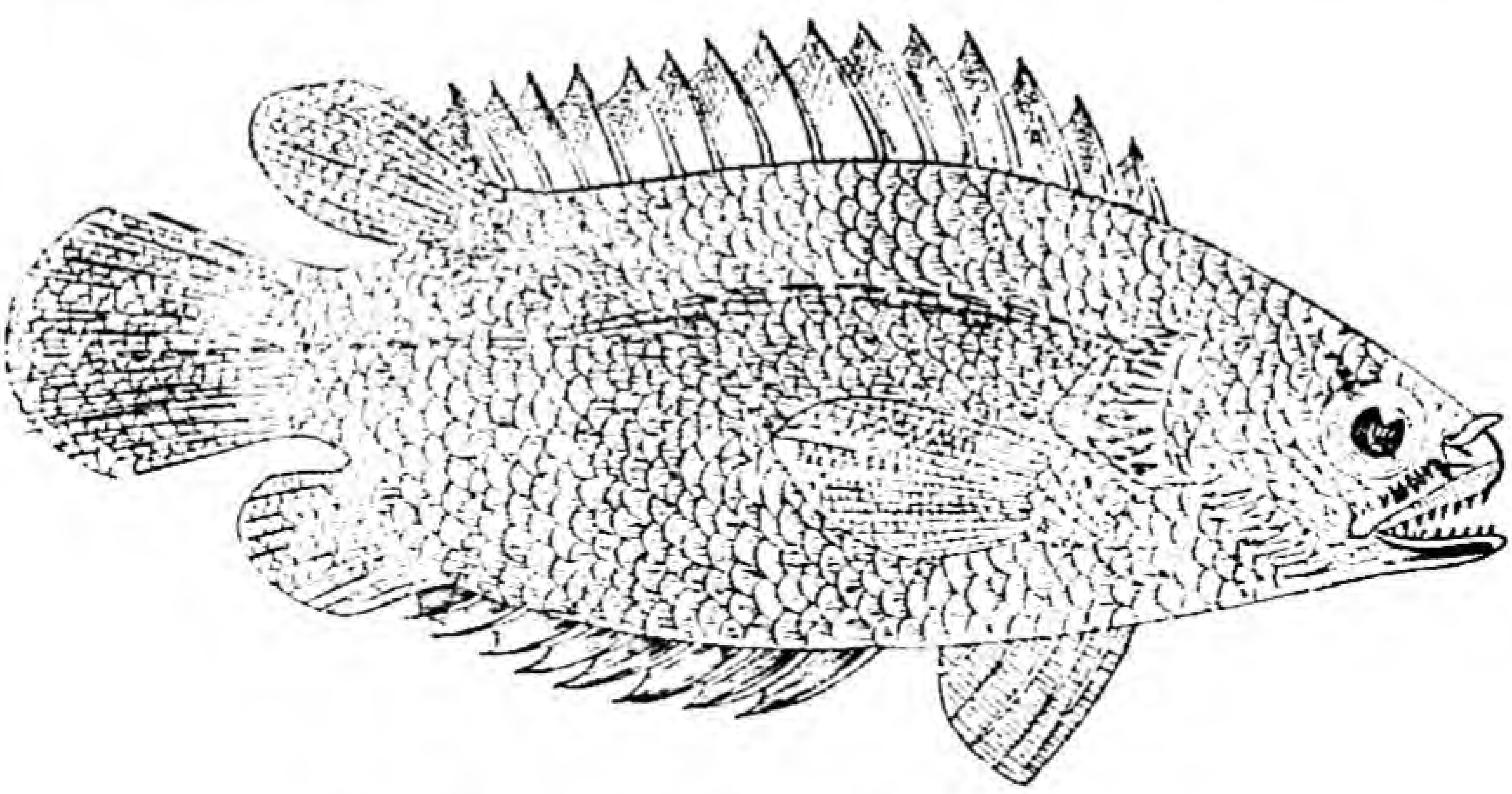


Fig. 36.12. The climbing perch (*Anabas*)

Climbing perch (Fig. 36.12). The climbing perch (*Anabas*) inhabits estuaries, rivers and tanks in India, Ceylon, Burma, the Malay Archipelago and the Philippine Islands. The operculum, the single dorsal fin and the ventral fin bear spines which enable the fish to travel long distances on land. When out of water, it respires air by an accessory air-breathing chamber present above the gills. Its climbing is doubtful.

Sea-horse (Fig. 36.13). The sea-horse (*Hippocampus*) lives among the weeds growing in coastal waters of the tropical and temperate seas. It has tube-like snout with a small terminal mouth. The head is at right angles to the body and resembles that of a horse. The entire body is protected in an exoskeleton of several rings. There is a single dorsal fin. The pectoral fins are reduced. The pelvic, ventral and caudal fins are absent. The tail is prehensile and the animal clings to the weeds with it. The sea-horse swims by means of the dorsal fin with the body held in a vertical position. The male has a brood pouch on the ventral side of its tail for keeping eggs.

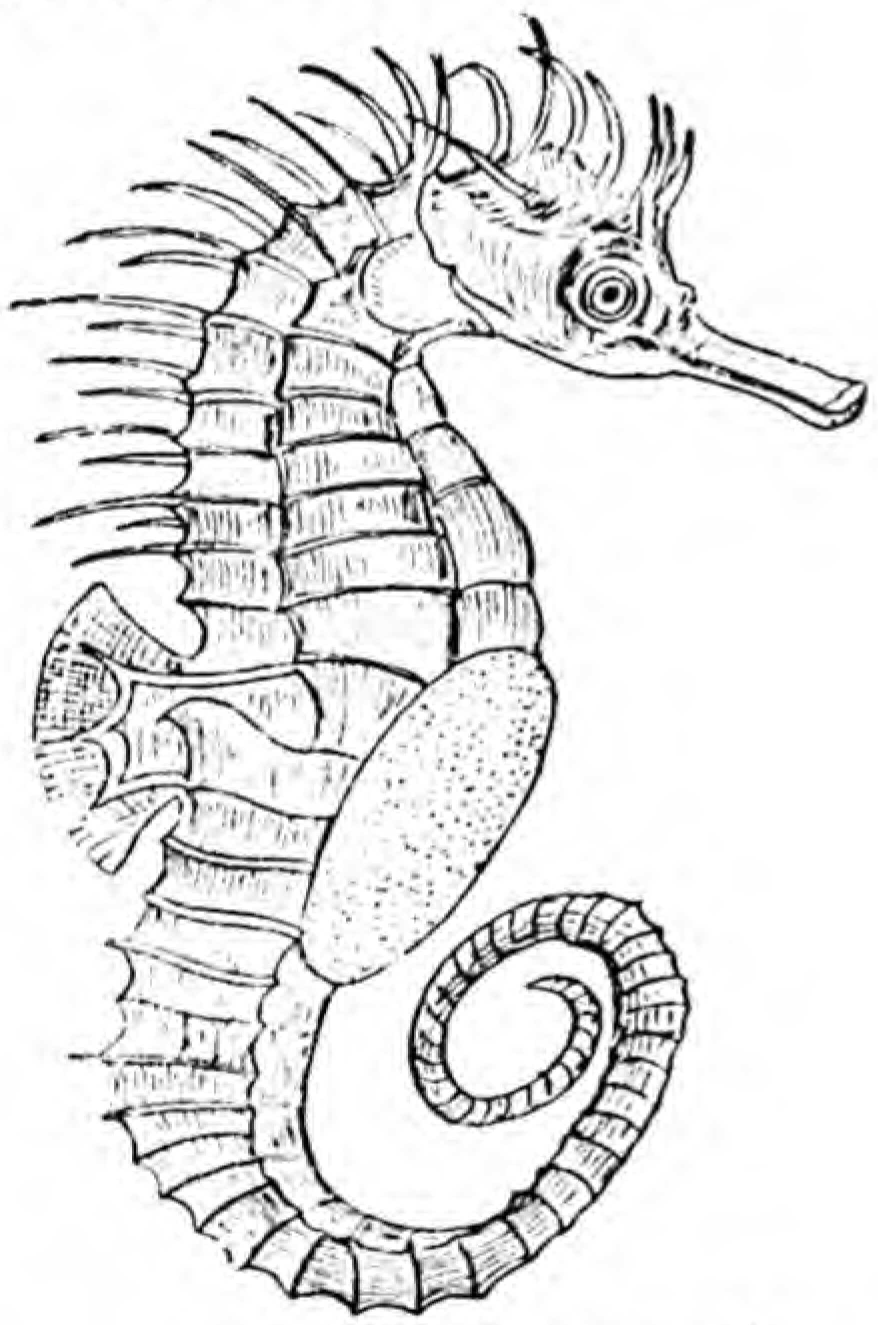


Fig. 36.13. Sea-horse (*Hippocampus*)

Fig. 36.14. The flat fish (*Solea*)

Flat fish (Fig. 36.14). The flat fish (*Solea*) is found on the sandy bottom of the tropical and temperate seas. The adult fish rests on the sea-floor on its left side and is very asymmetrical. Its body is greatly compressed from side to side. The upper or right side is pigmented and bears both the eyes on it. The lower or left side is colourless and without eyes. The dorsal and ventral fins are very long. There is no air-bladder. The fish is carnivorous.

The young flat fishes have a transparent, symmetrical body, equally pigmented on both sides and with one eye on each side. They swim in the open sea. Later on, they settle down on the sea-floor and acquire the above features.

African Mud-fish (Fig. 36.15). The African mud-fish (*Protopterus*) is one of the lung-fishes. It possesses internal nares for breathing air with lungs. Its paired fins are filamentous. It lives in the marshes near the rivers of Tropical Africa. It remains in shallow water and comes to the

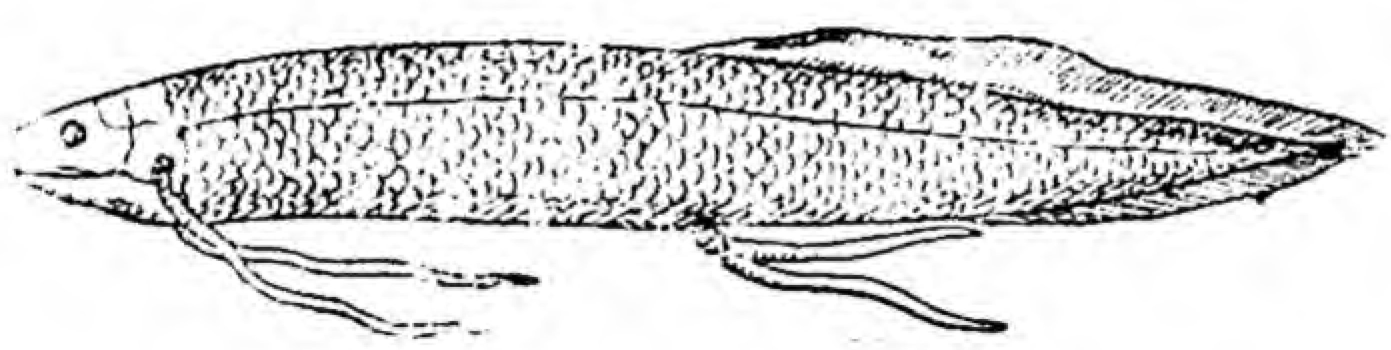


Fig. 36.15. The African mud fish (*Protopterus*)

surface at short intervals to breathe air. It is carnivorous in diet and is a voracious feeder. It eats worms, insects, snails and other fishes. It also exhibits cannibalism. It shows greater activity at night than during the daytime. It aestivates in the burrows made in the moist ground during the dry summer and comes out in the rainy season. The eggs are laid in a hole in the mud and are covered with grass. The young fish has a sucker for attachment and external gills for respiration.

CLASS 3. AMPHIBIA

The amphibians are cold-blooded vertebrates, capable of living both in water and on land. The skin is thin, moist, uncovered, respiratory and rich in glands. The larva always breathes by gills which may by retained throughout life or replaced by lungs in the adult. The olfactory sacs open into the buccal cavity by internal nares. The middle ear is present and has a single auditory ossicle. The appendages are in the form of pentadactyle limbs. The digits are without claws, nails or hoofs. The median fins, when present. are without, fin rays. The skull bears two condyles. There are ten pairs of cranial nerves. The heart is three-chambered: two auricles and one ventricle. There is a common outlet, the cloacal aperture, for the digestive and urinogenital systems. Development is usually accompanied by metamorphosis.

The class is divided into three orders: **Urodela**, **Anura** and **Apoda**.

Order (*i*) **Urodela**. It includes the salamanders. They have a long body and retain tail throughout life. They have two pairs of limbs which are nearly of equal size. The larval gills and gill-slits may or may not persist in the adult.

Salamander (Fig. 36.16). The salamander inhabits moist and shady places in Europe, Algeria and Syria. It is about 15—22 cm. long with a depressed head and trunk but rounded tail. The skin is smooth and shining. The dorsal surface of the body bears pores through which a viscid irritating fluid is secreted. It has a great power of regeneration and can grow lost limbs. It is a nocturnal animal. It creeps slowly on

land but swims actively in water with the tail. It feeds on worms, insects snails, etc. It breeds in water. There is no union of sexes. The female picks up the packets of spermatozoa deposited by the male. It is viviparous.

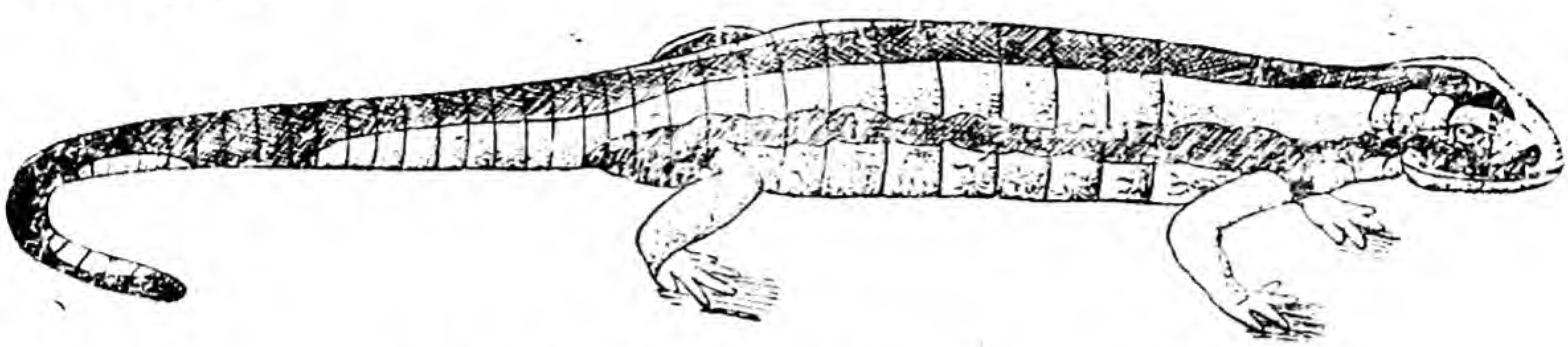
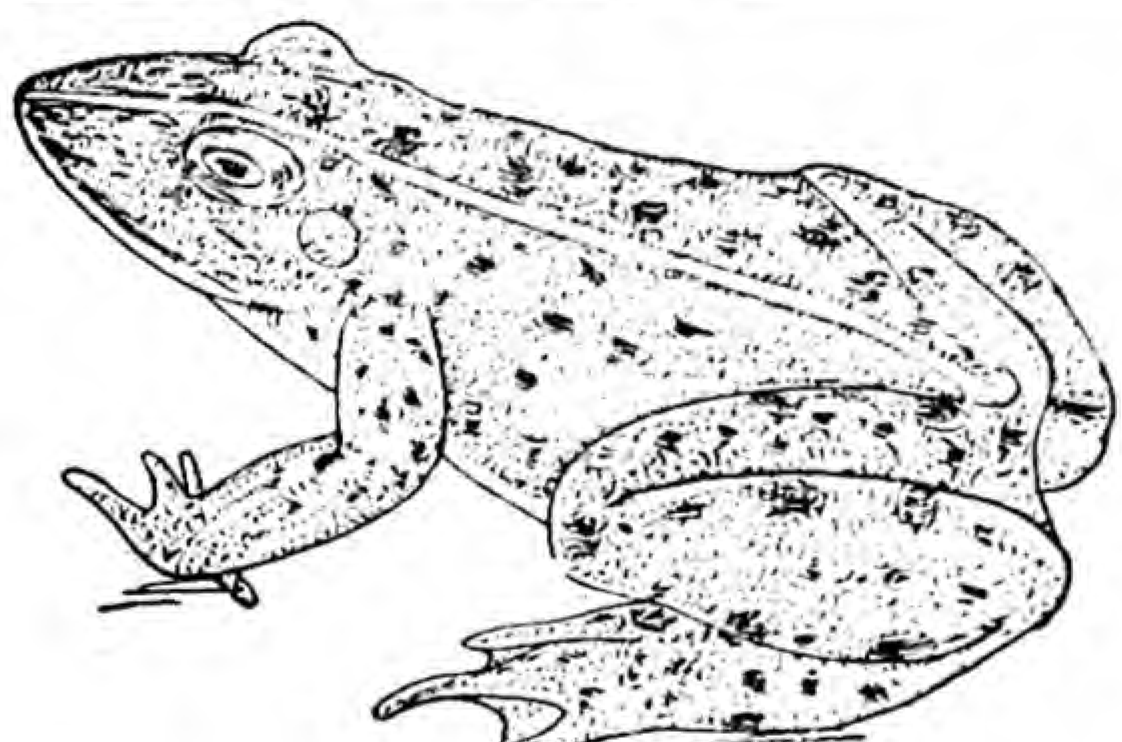


Fig. 36.16. Salamander (*Salamandra maculosa*)

Order (*ii*) Anura. It includes the frogs and toads. They are short bodied amphibians without tail in the adult stage. They have two pairs of limbs, of which the hind ones are the larger and adapted for swimming and leaping. Gills and gill-slits never persist in the adult.

TABLE 20

Differences between Frog and Toad

Frog	Toad
 Fig. 36.17. The Frog (*Rana*)	 Fig. 36.18. The Toad (*Bufo*)
Habitat 1. Frog lives in or near water.	1. Toad lives in dark shady corners of gardens hidden in grass or under stones and leaves. It visits water only for breeding.
Habits 2. Frog is diurnal.	2. Toad is nocturnal.
3. Frog lays eggs in a mass.	3. Toad lays eggs in a line.
External Characters 4. Skin is moist, smooth and slimy. It has respiratory function. It contains numerous mucous glands.	4. Skin is dry, rough and watry. It has no respiratory function. It contains numerous poison glands and fewer mucous glands.

Frog	Toad
5. Body is longer in size and has an olive-green colour irregularly mottled with dark patches.	5. Body is shorter in size and has an ash-grey colour.
6. Head is triangular.	6. Head is semi-circular.
7. There are no paratoid glands just behind the head.	7. There are two large paratoid glands just behind the head.
8. Fingers and toes lack black horny tips.	8. Fingers and toes have black horny tips
9. Webs between the toes are well developed.	9. Webs between the toes are rudimentary.
Internal Characters.	
10. Teeth are present in the upper jaw.	10. Teeth are absent in both the jaws.
11. Tongue is bifid.	11. Tongue is entire.
12. Liver has three lobes.	12. Liver has two lobes.
13. Ureters have separate openings into the cloaca.	13. Ureters have a common opening into the cloaca.
14. In the pectoral girdle, the episternum and omosternum are present and the epicoracoids overlap each other.	14. In the pectoral girdle, the episternum and omosternum are absent and the epicoracoids do not overlap each other.
15. Transverse process of the 9th or sacral vertebra are cylindrical and directed backwards.	15. Transverse processes of the 9th or sacral vertebra are flattened and directed outwards.
16. Periganglionic glands cover the origin of spinal nerves.	16. Periganglionic glands are absent.

Order (*iii*) **Apoda.** It includes the caecilians. They are long-bodied, worm-like, burrowing amphibians. The body is marked externally by rings which add to the worm-like appearance. The tail is practically absent as the anus is sub-terminal. The limbs and girdles are also lacking. The gills or gill-slits do not occur in the adults. They have dermal calcified scales embedded deep in the skin. The eyes are either absent or covered with skin and are functionless.

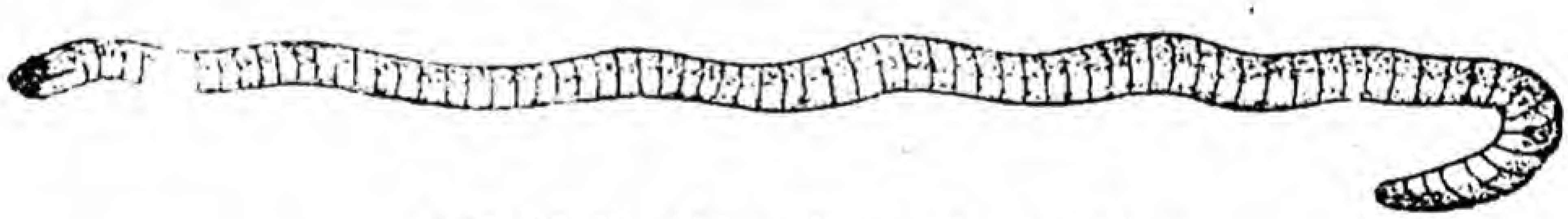


Fig. 36.19. Caecilian (*Uraetyphlus*)

Caecilian. The caecilian (Fig. 36.19) is found in India and West Africa. It lives in the moist ground. Cloaca in the male is eversible to form a copulatory organ.

CLASS 4. REPTILIA

The reptiles are cold-blooded predominantly terrestrial vertebrates. Their skin is without cutaneous glands (dry) and is covered by horny epidermal scales beneath which some have dermal bony plates. They typically possess two pairs of pentadactyle limbs which bears claws on the digits. Respiration is purely pulmonary, the gill-slits of the embryo being without gills and non-functional. The skull has only one occipital condyle. There are twelve pairs of cranial nerves. The heart is, as a rule, incompletely four-chambered, having two auricles and one ventricle partially divided by a septum. In Crocodilia, however, the heart is completely four-chambered. There are only two aortic arches, the right and the left, and they spring directly from the ventricles. There is a commor

outlet, the cloacal aperture, for the digestive and urinogenital systems. The external ear is often present. The middle ear has a single auditory ossicle. Males usually have copulatory organs. Eggs are large, with abundant food and limy porous shell. Eggs are laid on dry land. There is no larval stage and no metamorphosis.

The class has three important orders : **Squamata, Chelonia** and **Crocodilia.**

Order *i* Squamata. It includes the lizards and snakes. They have an elongated body covered by horny epidermal scales. The cloacal aperture is a transverse slit. The males have copulatory organs. The order Squamata is divided into two sub-orders : **Lacertilia** for the lizards and **Ophidia** for the snakes.

TABLE 21

Differences between lizards and snakes

Lizards	Snakes
1. Generally have a flattened body.	1. Have a long, cylindrical body.
2. Usually have two pairs of limbs.	2. Lack limbs and girdles.
3. Mouth is not distensible as the skull bones are fixed.	3. Mouth is highly distensible due to moveable skull bones.
4. Eyes may have movable lids.	4. Eyes lack moveable lids and are covered by transparent scale. This enables the snakes to give an unwinking stare.
5. Ears have external auditory canal and tympanum.	5. Ears lack external auditory opening and tympanum. Hence the snakes are unable to perceive air-borne vibrations.
6. Tongue is entire.	6. Tongue is bifid.
7. Have two functional lungs.	7. Have a single lung.
8. Possess urinary bladder.	8. Lack urinary bladder.
9. Sternum and episternum are present for ventral union of ribs.	9. Sternum and episternum are missing, hence ribs are free ventrally.
10. All teeth alike in all forms.	10. All teeth alike in non-poisonous forms. Poisonous forms have a pair of special teeth, the **fangs**, which are large and grooved or hollow for the flow of poison.
11. Moulting of horny layers of the skin occurs in pieces.	11. Moulting of horny layer of the skin occurs as a continuous slough.
12. Cannot protrude their tongue without opening the mouth.	12. Can protrude their tongue through a median notch in the lower jaw without opening the mouth. Tongue serves as an auxillary olfactory organ.

Wall Lizard or Gecko (Fig. 36.20) The common wall lizards is *Hemidactylus flaviviridis*.

(*i*) **Habitat.** The gecko inhabits the human dwellings throughout the warmer (tropical and sub-tropical) parts of the world.

(*ii*) **Habits.** The gecko is a nocturnal and carnivorous reptile. It is often seen capturing insects at night near the lights in summer. In winter, it hibernates in crevices and holes. It has a marked power of autotomy (breaking off a part of the body) and regeneration (regrowing the broken off parts) and uses this power for defence against enemies. If caught by tail, it breaks off the tail that engages the enemy by performing wriggling movements and enables the lizard to run away. The gecko sheds its skin periodically in flakes which are eaten up. It can change the shade of its colour to match with the background. The gecko is oviparous and lays almost spherical eggs with hard white shell. There is neither incubation nor care of the young ones.

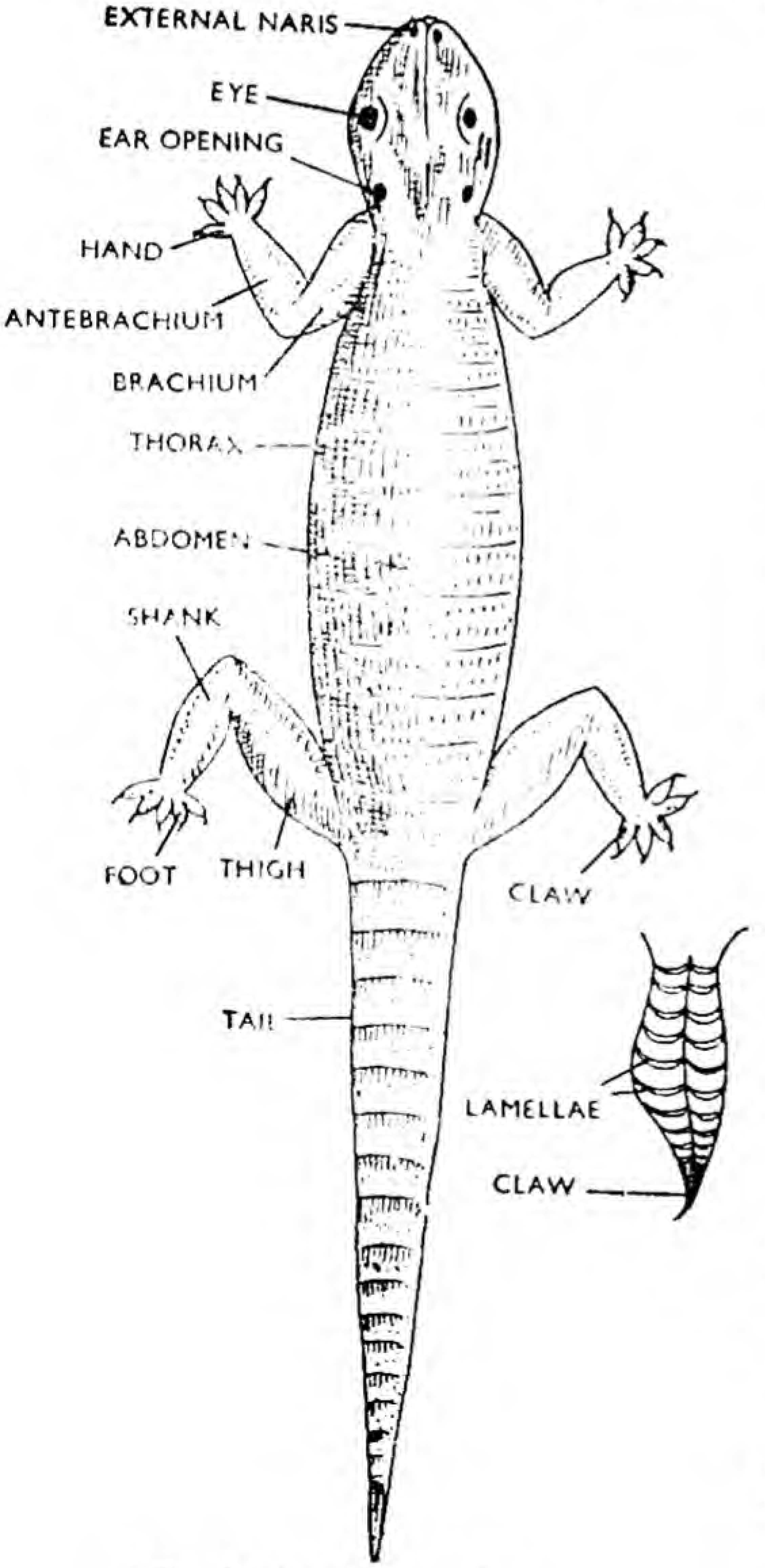


Fig. 36.20. The gecko (*Hemidactylus flaviviridis*)

The popular name is derived from the characteristic chirping sound of "yeko" or "gecko". The sound is produced by striking the tongue against the palate.

(*iii*) **External Characters.** The gecko (Fig. 36 20) has a depressed, dust-coloured body, about 15 cm. long. It is covered by granular scales and is quite rough. It is divisible into four regions : head, neck trunk and tail.

1. **Head.** The head is triangular and bears a wide terminal **mouth.** A little above the mouth are a pair of small apertures, the **external nares.** Further above and almost in the middle of head are two large eyes with vertical **pupil.** The eyes lack movable eye-lids but are permanently covered by transparent **nictitating membrane.** Below and behind the eyes are prominent slit-like **ear-openings.**

2. **Neck.** The neck is short and thick. It connects the head with the trunk.

3. **Trunk.** The trunk is arched above but flat below. It has two regions : anterior **thorax** which is

hard ventrally and posterior **abbomen** which is soft ventrally. **The trunk** bears two pairs of short but stout, outwardly directed **limbs on** the sides and a transverse slit, the **cloacal aperture**, at its junction **with the tail.**

The **fore-limbs** arise from the sides of the anterior part of the **thorax.** They are shorter than the hind-limbs. A fore-limb consists of three segments : **upper arm** or **brachium, fore-arm** or **antebrachium** and **hand or manus.** The hand further consists of the **wrist** or **carpus,** the **palm or metacarpus** and five **fingers** or **digits**, each armed with a sharp, curved, horny **claw**.

The **hind-limbs** arise from the sides of the posterior part of the abdo-**men.** They are larger than the fore-limbs. A hind-limb also has three segments : **thigh** or **femur, shank** or **leg and foot** or **pes**. The foot further shows three regions : **ankle or tarsus, instep** or **metatarsus** and five **toes or digits,** all bearing sharp, curved, horny **claws.**

The digits, fingures as well as toes, are dilated and bear on the ventral side adhesive pads for creeping over the vertical surfaces and ceilings. The pad consists of two rows of transverse lamellae (Fig. 36.20) and provide adhesion by vacuum principle. They are first pressed over the surface to drive out air and then partially raised to create vacuum under-neath. The lamellae are further beset with tiny hair-like outgrowths which secure adpression to even the slightest irregularity of surface. The claws of the digits arise from within the tips of their dilated pads.

4. Tail. The tail is banded. It is thick and flat at the base but taper posteriorly. It is remarkably brittle at its base and is replaced, if lost. The new tail lacks vertebrae.

Economic Importance. The gecko is often regarded as poisonous and even capable of poisoning any surface it happens to cross. Actually, it is perfectly harmless, rather beneficial, as it keeps a steady check on harmful insects.

Flying Dragon. The flying dragon (Fig. 36.21) inhabits the Indo-Malayan, countries. It has a depressed body whose sides extend outwards as a pair of large wing-like membranes. The latter are supported by 5 or 6 elongated ribs and can be folded like a fan. The tail is very long and slender but not brittle. The throat bears three pointed appendages. The "wings" are used for taking long leaps from one tree to another.

Chamaeleon (Fig. 36.22). The chamaeleon is found in South India, Ceylon, Africa and Arabia. It is an arboreal lizard well-known for changing colours. Its head bears a casque and lacks tympanum and tympanic cavity. The eyes are very large. The right and left eyes are independently movable so that the animal seems to squint. The tongue is club-seaped, greatly extensile and covered with sticky mucus. It can catch the prey (insects) 17—20 cm. away from the animal. Two digits are permanently opposed to the other three so that the hands and feet form grasping organs. The tail is prehensile and is rolled downwards.

It is not brittle and is not renewed, if lost. The eggs are laid in the ground.

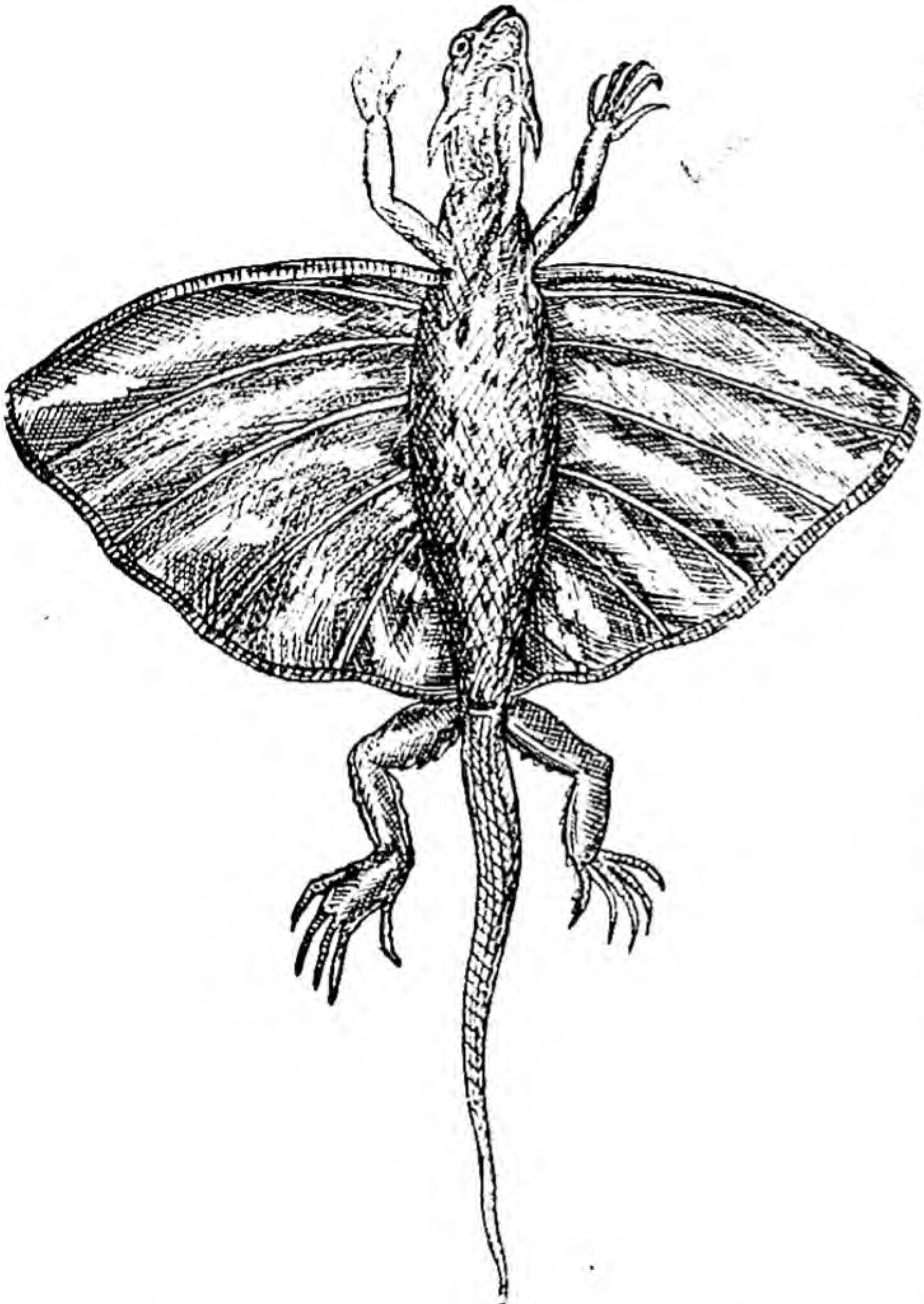


Fig. 36.21. The flying dragon (*Draco*)

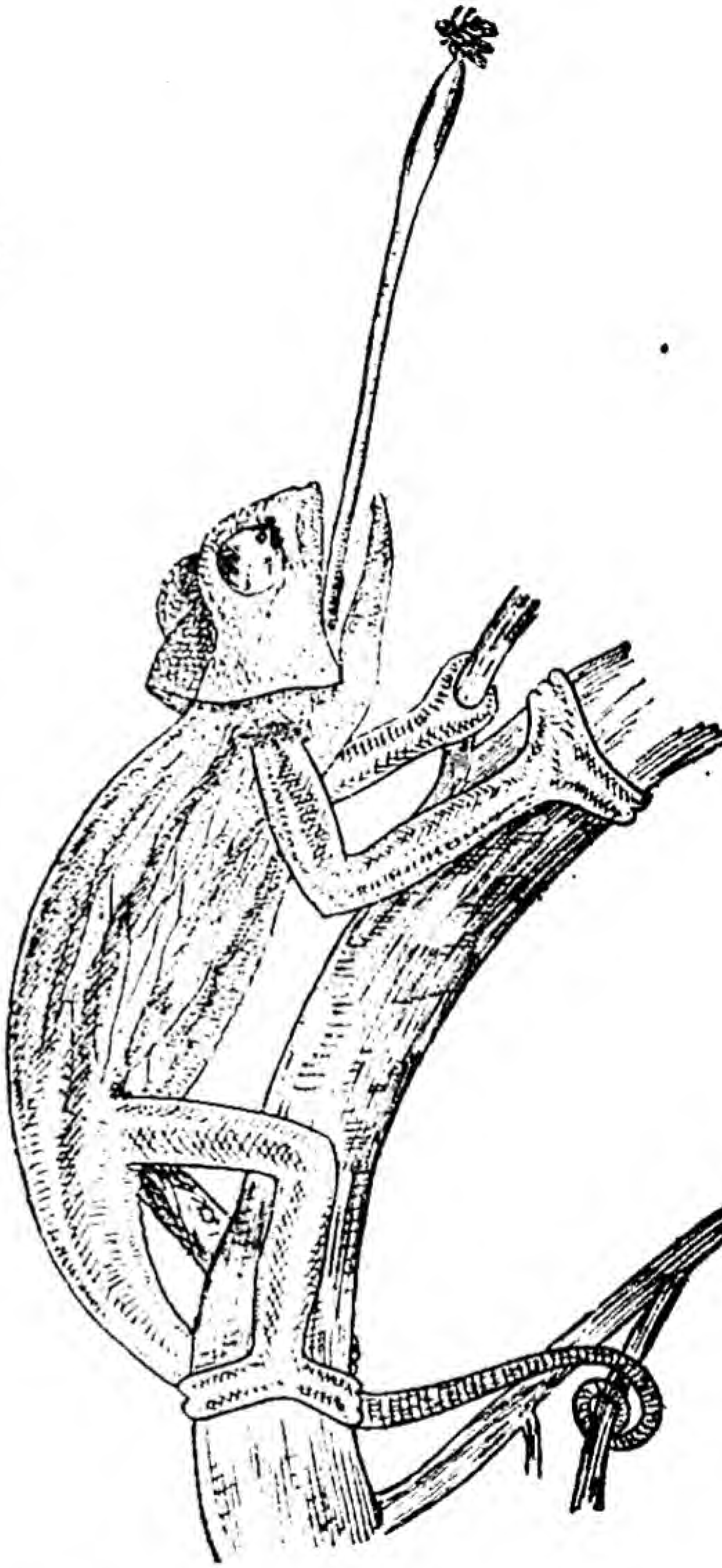


Fig. 36.22. Chamaeleon (*Chamaeleon*)

Snakes. The snakes crawl gracefully on a rough surface, acquiring grip by pressing ribs against the surface. They are helpless on a smooth surface like glass plate and polished floor. The snakes live in burrows of other animals as they themselves are usually unable to dig burrows. They usually do not attack man unless molested. They are mainly nocturnal and carnivorous. Their food consists of various types of vertebrates like fishes, frogs, lizards, other snakes, small birds and mammals. The prey is swallowed entire.

The majority of snakes are non-poisonous. The common poisonous

snakes found in India are : cobra krait, viper and sea-snakes. The rat-snake, python and boa are examples of non-poisonous snakes.

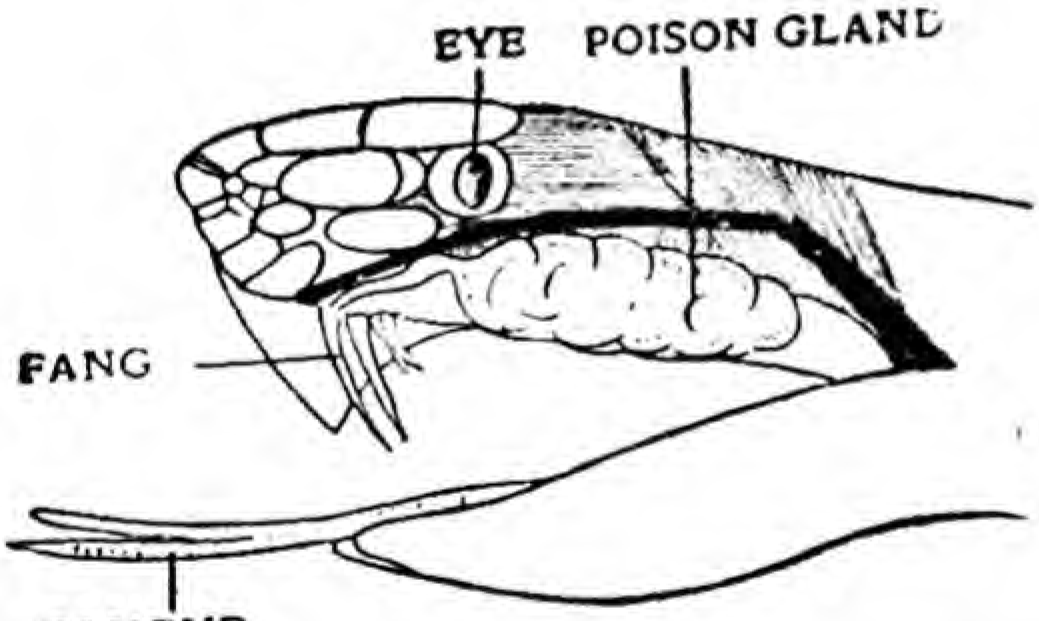


Fig. 36.23. Head of a poisonous snake showing the location of poison fang and poison gland

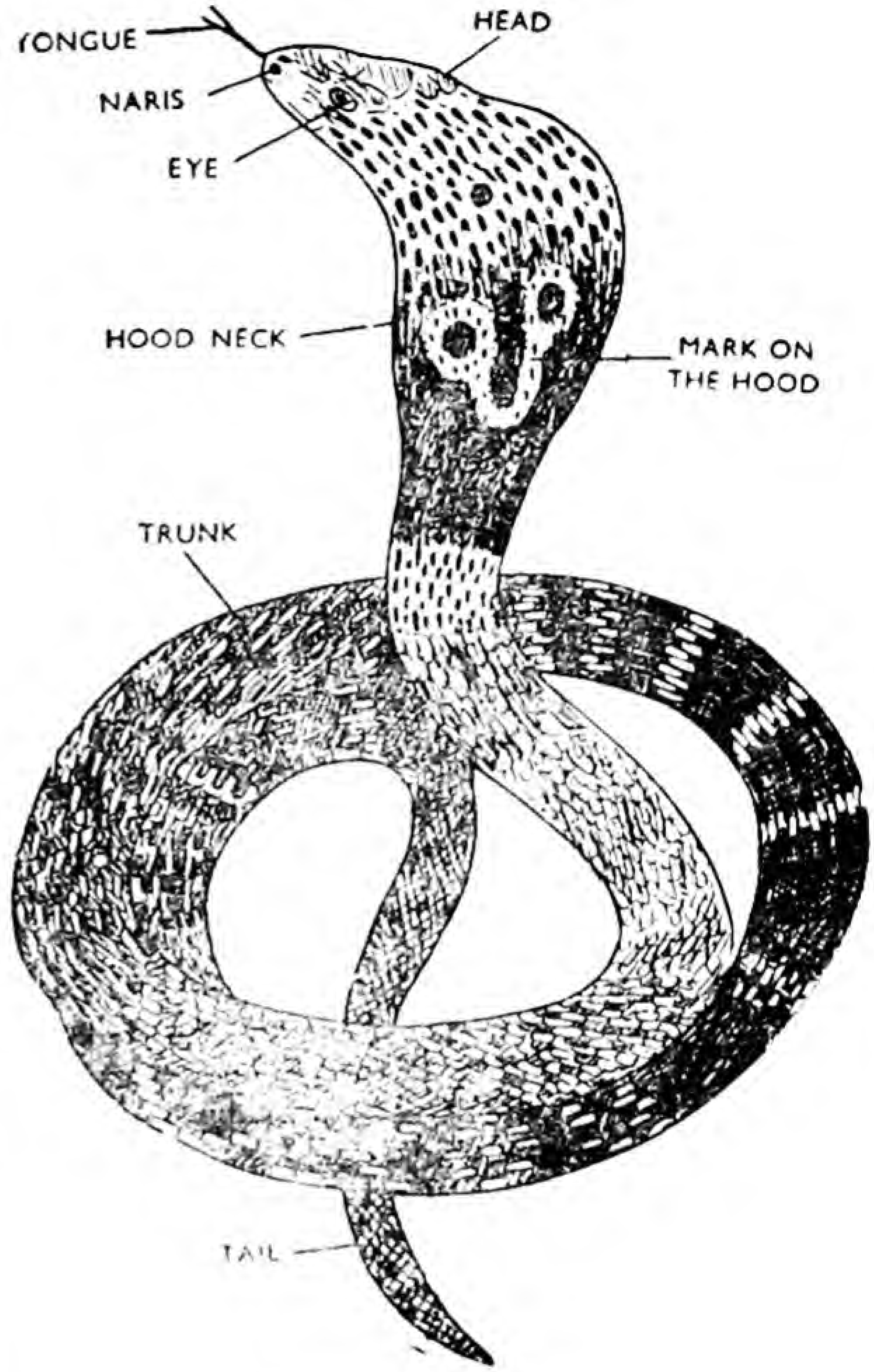


Fig. 36.24. The cobra (*Naia*)

Rat Snake or Dhaman. It is found in India, Pakistan, Ceylon, Baluchistan and Afganistan. It grows to 210 cm. It has an elongated head, distinct from the neck and covered with large shields. Its trunk shows a prominent ridge of the back-bone and is covered with smooth scales. The tail is quite long and has two rows of scales on its under-surface. The snake feeds on rats, mice and squirrels.

Cobra. (Fig. 36.24). The cobra (Naia) is found in South Asia and Africa. It is about 180 centimetres long. It can expand its neck into a broad hood. It prefers places where it can easily retire, *e.g.* deserted ant-hills, heaps of stones, piles of logs and rat-infested houses. It feeds on frogs, lizards, birds and rats. It hunts in the late afternoon

and in the evening. It is not vicious by nature and attacks only in self-defence. Animals like peacocks, mongoose and pigs are its enemies.

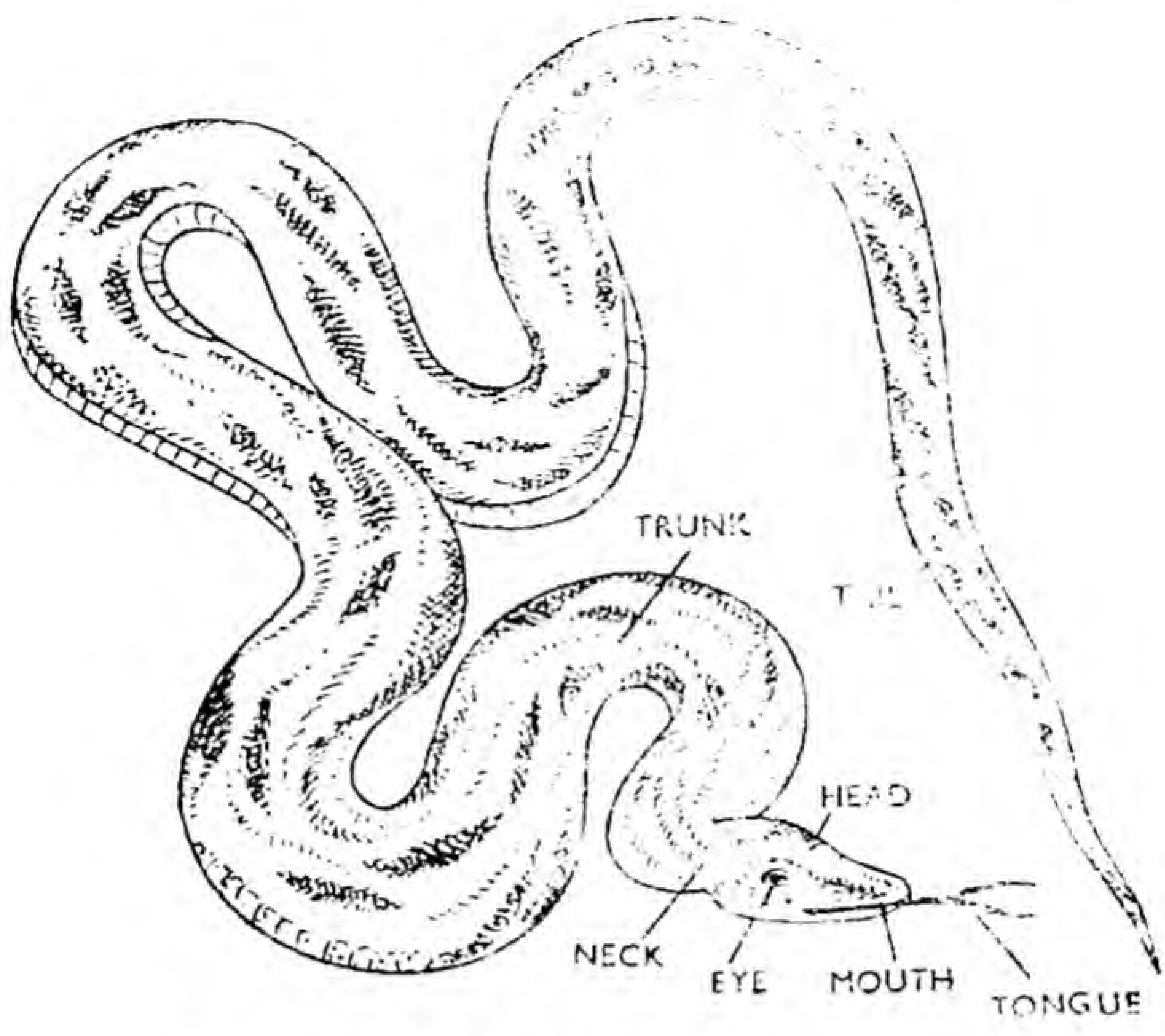


Fig. 36.25 A. Viper (*Vipera*)

Vipers. The vipers (Fig. 36.25 A) are confined to old world (Asia, Europe and Africa). They have a broad flat head usually covered with small scales, a narrow neck, a heavy trunk with broad plates on the

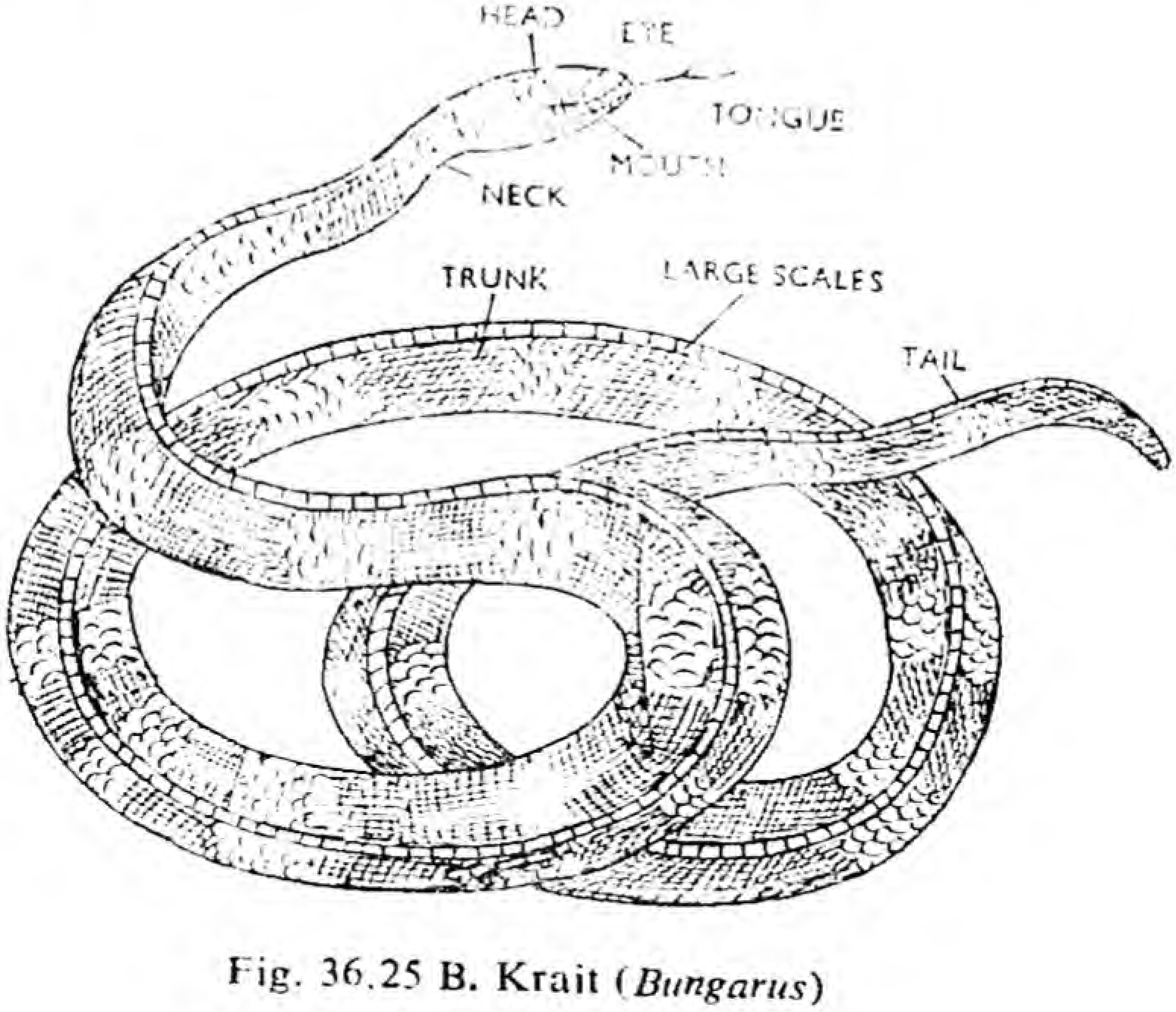


Fig. 36.25 B. Krait (*Bungarus*)

belly and a short tail with two rows of scales on the underside. They lie in wait for the prey, strike it, wait for it to die, track it down and then swallow. They are viviparous.

Kraits. The kraits (Fig. 36.25 B) occur in South-Eastern Asia. They possess large shields on the head, broad plates on the belly, a median row of large scales on the back and a cylindrical tail with a single row of scales on the underside.

Sea-snake (Fig. 36.26). The sea-snake is found in the Indian and Pacific Oceans. It varies in length from 90 to 240 centimetres. The

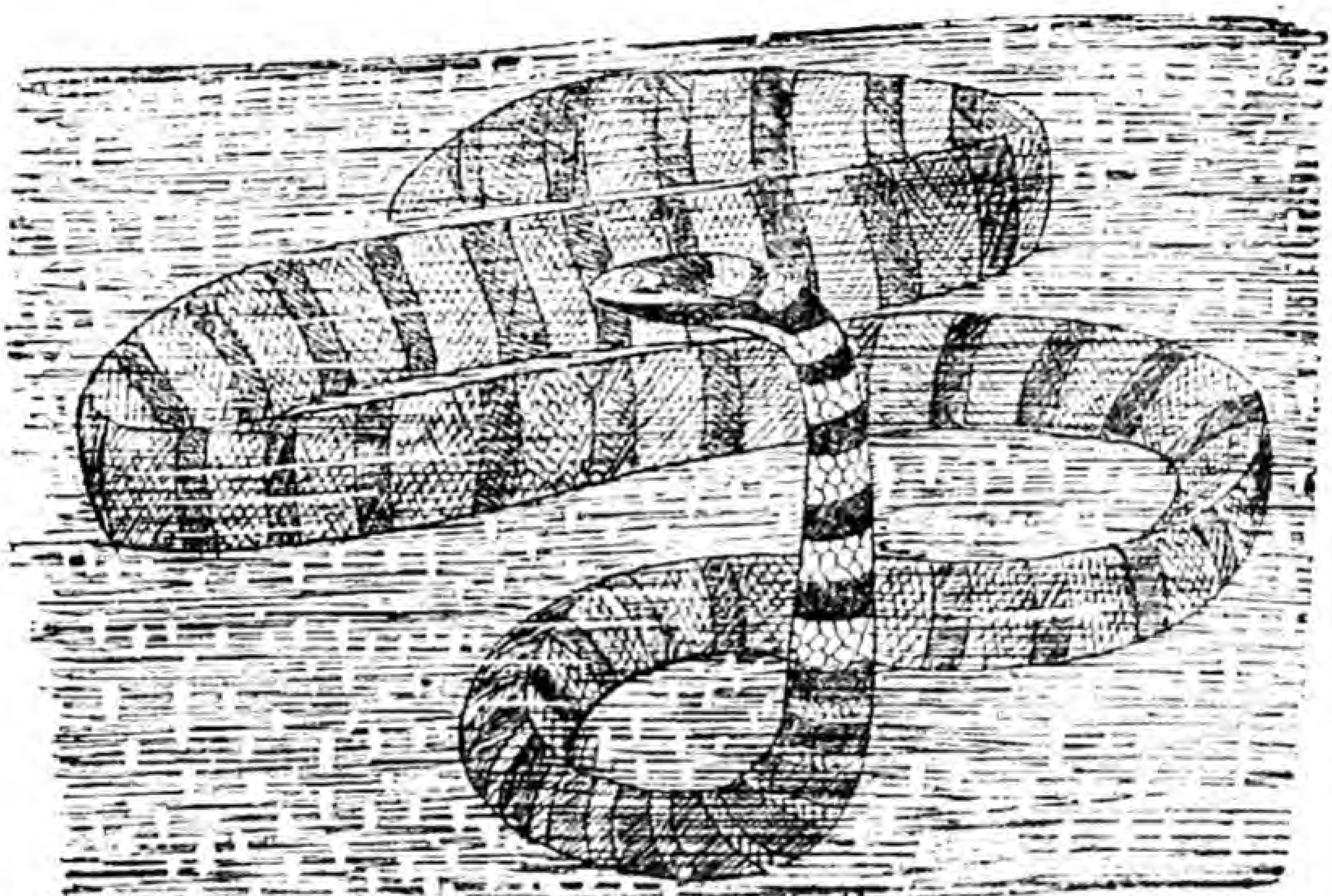


Fig. 36.26. Sea-snake

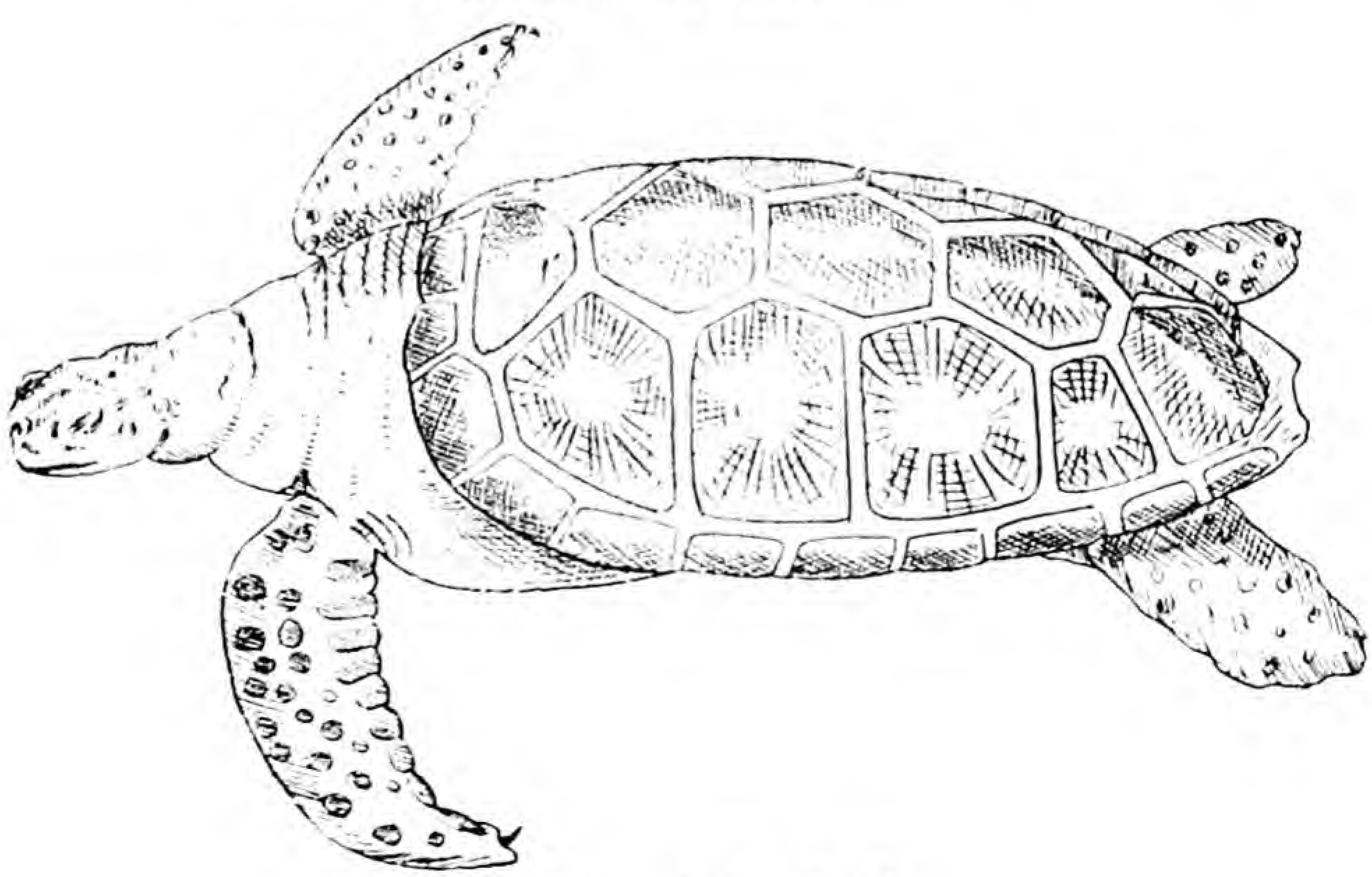


Fig. 36.27. Turtle

head and neck are very slender and the trunk becomes thicker posteriorly. The tail is laterally compressed to form a swimming organ. Sometimes the body may also be similarly compressed. The nostrils are situated on the top of the head. The scales covering the body are almost similar all over. The snake feeds on fishes and is viviparous.

Order (*ii*) **Chelonia.** It includes the tortoises and turtles. They possess a short and wide trunk which is enclosed in a bony case consisting of two parts : the dorsal arched **carapace** and the ventral flat **plastron.** The head, limbs and tail can also be withdrawn into this case at the time of danger. The bony case is usually covered by an exoskeleton of epidermal horny plates which form the popular **'tortoise shell'** The jaws are without teeth and covered by horny sheaths. There is no sternum. The tongue is attached to the floor of the buccal cavity and is not protrusible. The cloacal aperture is a longitudinal slit.

TABLE 22.

Differences between Tortoises and Turtles

Tortoises	Turtles
1. Live on land and in fresh water.	1. Live mainly in the sea, are helpless on land.
2. Limbs have distinct digidts, the majority (4 or 5) of which bear claws.	2. Limbs modified into paddles for swimming, digits indistinct and only two bear claws.
3. Carapace is oval and highly domed.	3. Carapace is heart-shaped and not very high, being streamlined for aquatic life.
4. Head can be completely withdrawn under the carapace.	4. Head can be only partially withdrawn under the carapace.
5. Hibernate in winter and aestivate in dry summer periods.	5. Do not hibernate or aestivate due to uniformity of weather conditions in the sea.
6. Some tortoises are edible and are called **terraipns**	6. Eggs of turtles are edible.

Order (*iii*) **Crocodilia.** It includes the crocodile, alligators and gavials. They are large-sized lizard-like, fresh-water reptiles. The skin is covered by epidermal scales, below which there are dermal bony plates either only on the dorsal side or on both the dorsal and ventral sides. The tail is very large and laterally compressed to assist in swimming. The limbs are comparatively short. Digits of the hind-limbs are webbed. External nares can be closed with valves when under water. Cloacal aperture is longitudinal slit. The copulatory organ is present in the males.

The crocodiles differ from typical reptiles and approach mammals in certain features. The teeth are lodged in sockets. The maxillae, palatines and pterygoids of two sides are united in the middle to form a hard palate. The internal nares have, consequently, shifted

backwards. The heart is four-chambered. A muscular diaphragm partially separates the thoracic and abdominal cavities.

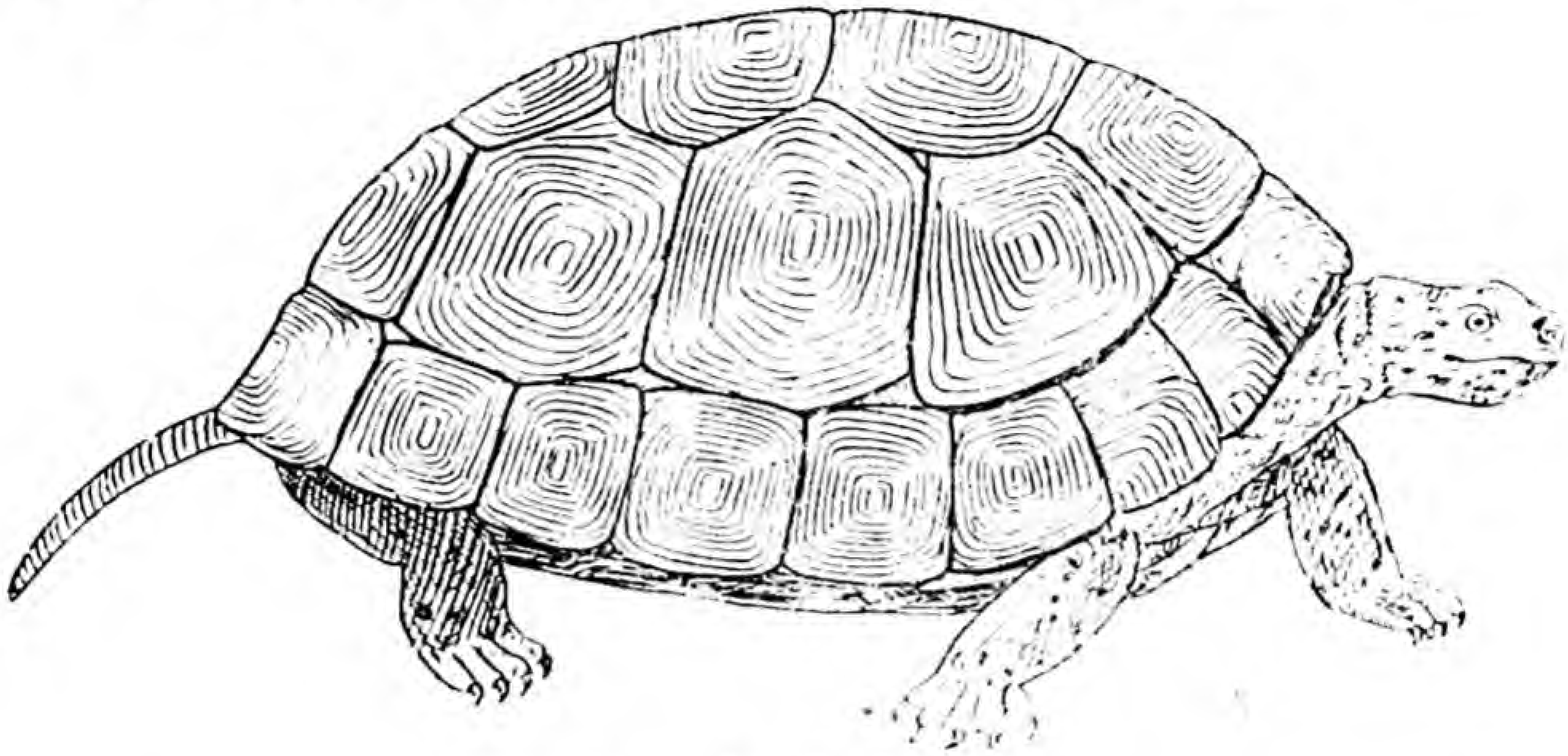


Fig. 36.28. Tortoise (*Testudo*)

Indian Crocodile or **Mugger** (Fig. 36.29). The Indian crocodile (*Crocodilus palustris*) is perhaps the largest living reptile and measures about 360 centimetres. It is found in the rivers, tanks and marshes of India, Pakistan, Burma, Ceylon, Baluchistan and Malay Islands. In summer, when the tanks and marshes dry up, it wanders about on land in search of water. If unable to find water, it aestivates or sleeps in the

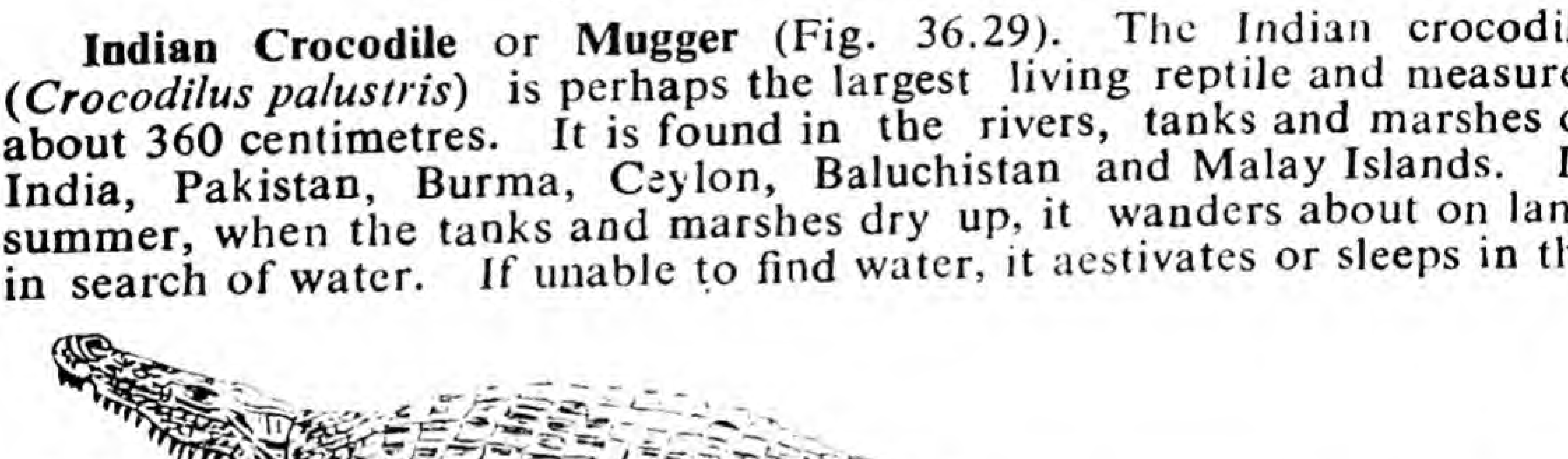


Fig. 36.29. Crocodile (*Crocodilus palustris*)

mud to come out after the rains. It is well adapted for aquatic life. Slightly webbed fingers, broadly webbed outer toes, and laterally-compressed tail help in swimming. It can close the nares and ear openings with special valves when in water. It has a valve in the pharynx for enabling it to feed in water without filling the lungs. During the daytime, it is often seen basking on the sandy banks. It is carnivorous. It is a timid creature and quickly hides itself on the sight of man. The eggs are laid in the sand and are looked after by the female.

CLASS 5. AVES

The birds are warm-blooded vertebrates adapted for flight in the air. Their body is steamlined to offer minimum resistance to wind. The skin is almost dry and is covered with an epidermal

exoskeleton of feathers all over and of scales on the legs and feet. The feathers serve as an insulating layer to conserve body heat. There are two pairs of pentadactyle limbs of which the fore-ones are modified into wings for flight and the hind ones to support the body on land. The birds are, thus, **bipeds**. The digits of the hind-limbs bear claws. The bones contain air spaces which reduce the body weight. There is a well-developed **sternum** generally with a **keel** for the attachment of powerful wing muscles. A special system of **air-sacs,** connected with the lungs and extending into flight muscles and certain bones, is developed to help in respiration during flight and to regulate body temperature in the absence of sweat glands. The respiration is purely pulmonary. The skull bears a single **occipital condyle**. The upper and lower jaws form a **beak** which lacks teeth and is covered with horny sheath. The heart is four-chambered having two auricles and two ventricles. There is a single aortic arch which curves to the right side. An external ear comprising a short meatus is always present. There is a common outlet for the digestive and urinogenital systems. A chamber called the **syrinx** is developed at the point of bifurcation of the trachea into bronchi for the production of sound. The females have a single ovary. The males usually lack copulatory organs. Copluation occur by mere cloacal apposition. There is no urinary bladder. All birds are **oviparous.** They lay large eggs with much food and limy shell.

The birds are well-known among the vertebrates for their sexual dimorphism, seasonal migrations, art of nest building, affection for the male, melodious songs and parental care.

Pigeon (Fig. 36.30)

Habitat. The pigeon (*Columba livia*) is found in most of Europe and Asia resting at night and making nests on the projections of buildings, particularly the old ones.

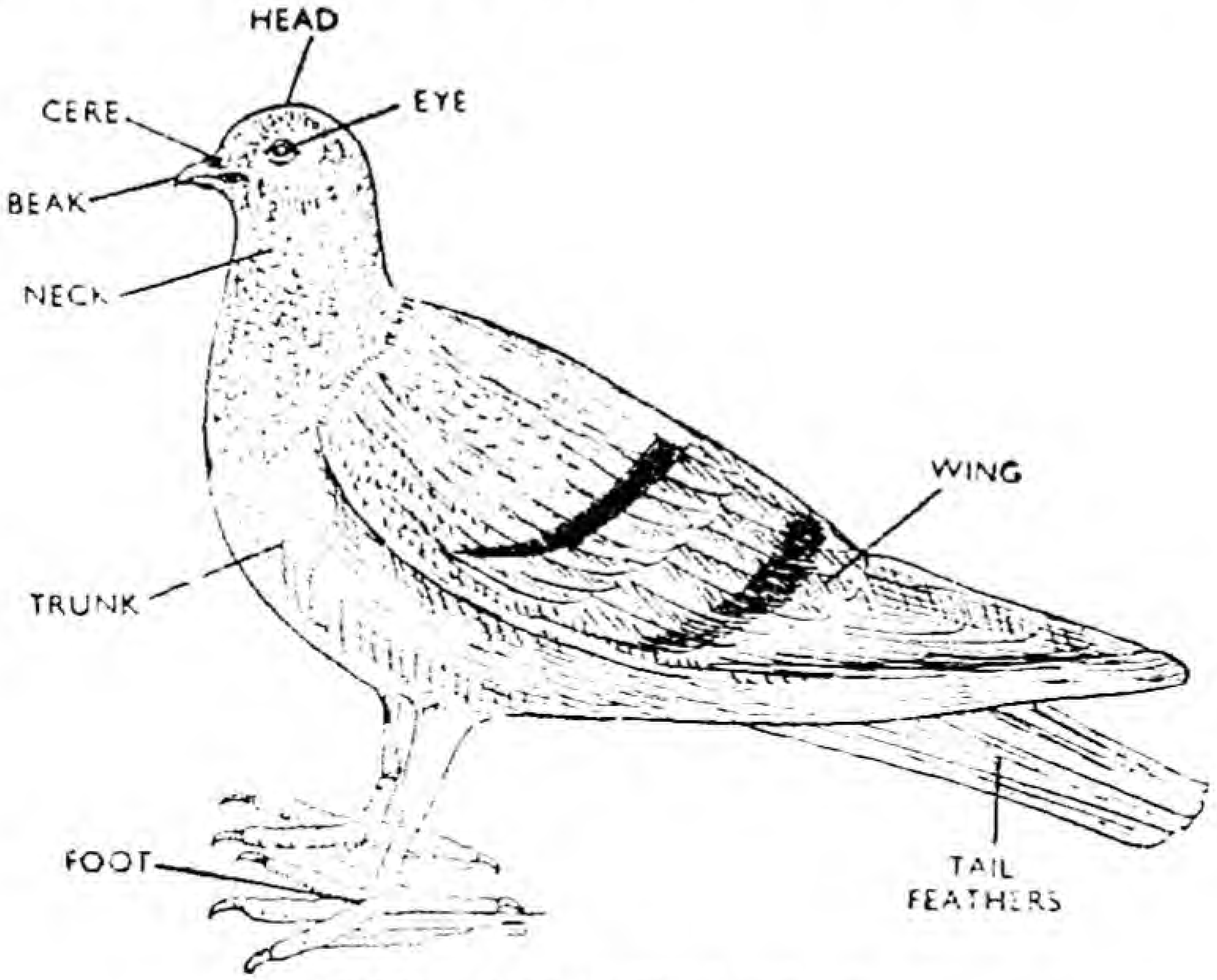


Fig. 36.30. Pigeon (*Columba livia*)

Habits. The pigeon is a gregareous bird and feeds on grains, seeds and young green shoots. It is monogamous, *i.e.* one male lives in the company of a single female, and displays a brief courtship before copulation. Its nest is very crude. It is made of dry grass and twigs. Only two, rarely one, eggs are laid by the female in spring or summer. The eggs are white in colour. They are incubated by both the parents. The period of incubation extends over fourteen to eighteen days. The young are fed by the mother on "pigeon's milk" which is a creamy fluid secreted by her crop during the breeding season. The pigeon is not capable of rapid locomotion on land because of short legs. It is attacked at night by cats and owls.

External Characters. The body of the pigeon (Fig. 36.30) is about 32 cm. long. It is streamlined to offer minimum resistance to wind during flight. It has a blue-grey colour with a beautiful blue-green sheen in the neck. It is covered with feathers all over except the feet. The feathers lie flat and overlap from front to rear to provide a smooth contour. The body is divisible into four regions: **head, neck**, **trunk** and **tail**.

1. **Head**. The head is small and rounded. It is prolonged in front into a pointed **beak**. The beak actually consists of upper and lower jaws covered with horny sheath. The **mouth** is terminal and has a wide gape. It extends along the entire border of the beak. At the base of the beak, on the upper side, is a patch of naked, soft, swollen skin. This is known as the **cere**. Close to the anterior margin of the cere are a pair of oblique slits, the **external nares** or **nostrils**. On either side of the head is a prominent circular eye. Each eye is provided with upper and lower eye-lids and a well developed semi-transparent **third eye-lid** or **nictitating membrane**. The latter can by pulled across the eye-ball form the anterior corner of the eye. Behind each eye and covered with feathers is a small rounded aperture, the ear or **auditory opening.** It leads by a short tube, the **external auditory meatus,** to the tympanic membrane.

2. **Neck**. The neck connects the head with the trunk. It is long and mobile. It is almost vertical and slightly widens towards the trunk.

3. **Trunk**. The trunk is boat-shaped. It has a prominent midventral ridge, the **keel** or **carina**. At its hind end, on the ventral side, is a transverse slit, the **cloacal aperture**. It is a common outlet for the faeces, urine and genital products. The trunk bears two pairs of limbs.

(*a*) **Fore-limbs**. The fore-limbs are at the anterior end of the trunk. They bear long feathers and form the flying organs or **wings**. The feathers increase their surface area considerably when they are extended for flying. Each fore-limb or wing consists of three parts : **upper arm** or **brachium**, the **fore-arm or antebrachium** and the **hand** or **manus** with three **fingers or digits**. When the bird is at rest, the three parts of the wing are folded against the sides of the trunk like the letter 'Z'. A fold of skin, termed the **prepatagium**, stretches between the upper arm and the fore-

arm on the front or pre-axial side. A similar but smaller fold, the **post-patagium**, joins the proximal part of the upper arm with the trunk on the hind or post-axial side.

(*b*) **Hind-limbs.** The hind-limbs are at the posterior end of the trunk. They are not directed outwards as in the frog or lizard. They are almost vertical to balance the entire body on them. This gives **bipedal gait** to the bird. Each hind-limb consists of three parts: the **thigh**, the **shank** and the **foot** or **pes** with four **toes** or **digits**. The first digit or **hallux** is directed backwards while the others (2nd, 3rd and 4th) face forward. All the digits end in horny claws. The feet are covered with horny epidermal **scales**. Rest of the hind-limbs are clothed in feathers.

4. **Tail.** The tail is very short and stumpy. It is known as the **uropygium**. It bears long tail feathers arranged in a semi-circle. On its upper surface is a small papilla which bears the opening of the **oil or uropygial gland.** The oil renders the feathers waterproof.

Feathers (Figs. 36.31 and 36.32). The feathers form exoskeleton of the birds. They develop from the outer part of the skin or epidermis. They do not cover the body uniformly. They are arranged in definite feather tracts, the **pterylae,** separated by featherless areas, the **apteria.** The spread of the feathers is, however, sufficient to cover the apteria so that the body seems to be fully covered. The arrangement of feathers on the body is called **pterylosis**. The feathers are shed or **moulted** annually. This generally happens in late summer.

The feathers are of several types, namely, quill feathers, coverts, contour feathers, filoplumes and down feathers.

(*i*) **Quills**. The quills are the large feathers found in the wings and the tail. A quill feather has a long stiff central axis called **shaft** or **scapus** or **stem.** Small proximal part of the stem is hollow, translucent and cylindrical. This is termed the **calamus** or **quill**. Long distal part of the stem is solid, opaque and ventrally grooved. This is called the **rachis.** The proximal end of the calamus has a small hole, the **inferior umbilicus**. At the junction of the calamus and the rachis is another minute aperture, the **superior umbilicus.** The rachis bears on either side a thin broad membrane, termed the **vane** or **vexillum.** The vane is composed of series of slender parallel filaments, the **barbs,** which arise from the rachis and extend outwards and upwards. Each barb (Fig. 36.32) itself bears a fringe of small processes, the **barbules,** along either border. The distal barbules of each barb bear minute **hooklets** or **barbicels** which fit into grooves of the proximal barbules on the next adjacent barb. Thus, all the barbs are firmly fastened together and form a single continuous surface to offer resistance to air. A tuft of separate barbs occurs near and covering the superior umbilicus. This is called the **aftershaft** or **hyporachis.**

The quill feathers found in the wings are known as the **wing-quills** or **remiges** (singular **remex**). There are 22 such feathers in each wing. Of these, 12 are attached to the fore-arm and are called the **secondaries**

while 11 are fixed to the hand and are termed the **primaries**. The quill feathers of the tail are called the **tail-quills** or **rectrices** (singular **rectrix**). There are 12 such feathers. They are arranged in a semicircle around the tail.

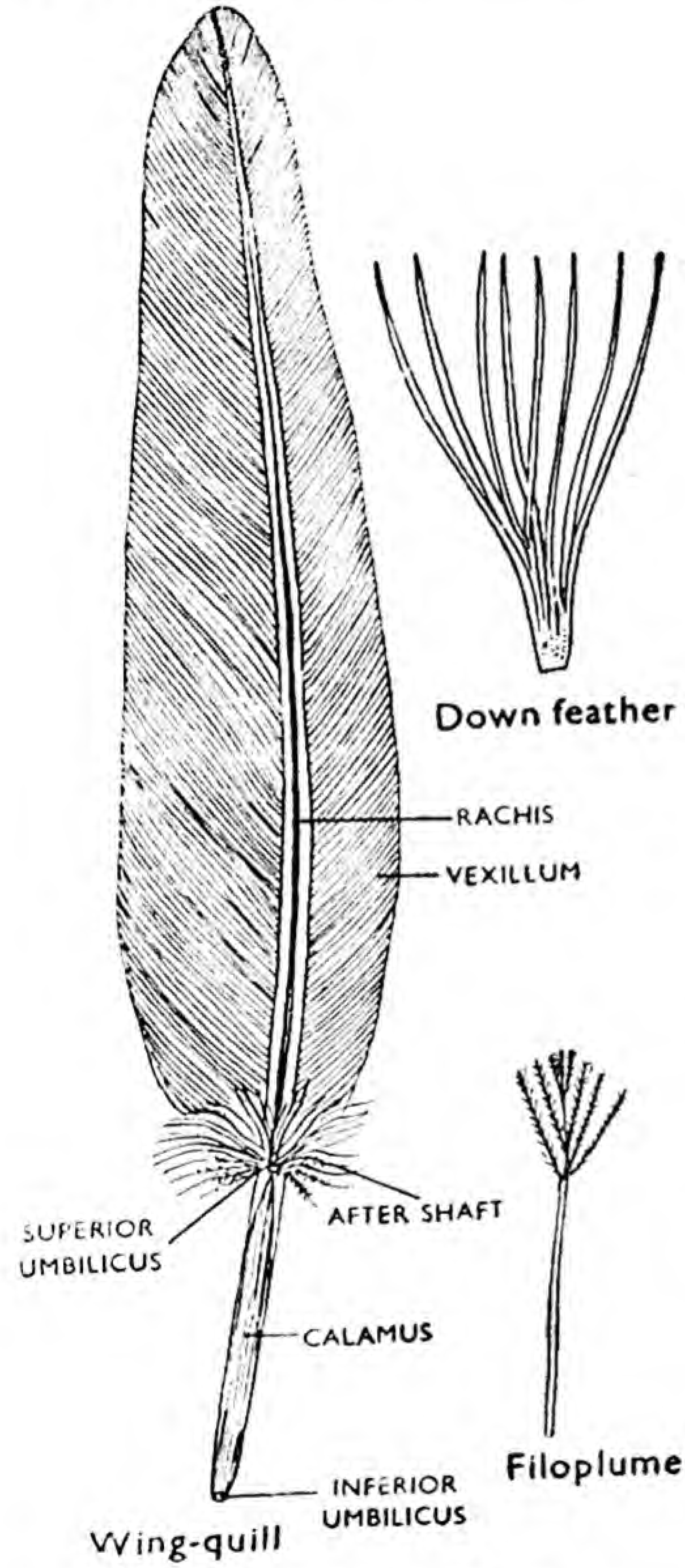


Fig 36.31. Feather types

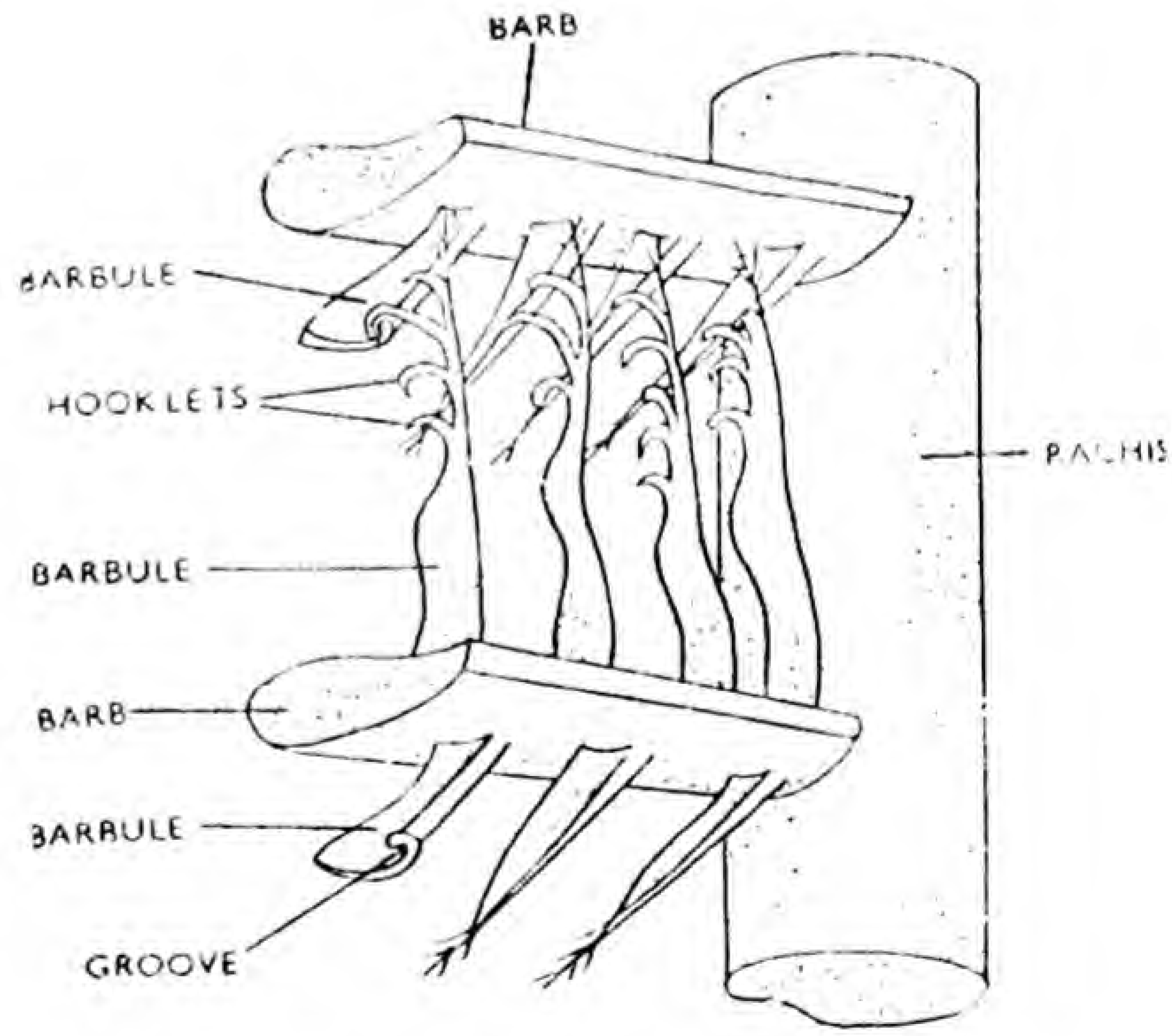


Fig. 36.32. A part of rachis magnified to show barbs, barbules and hooklets

(*ii*) **Coverts**. The coverts are small feathers found at the bases of the wing and tail-quills. They are like the quills except that they are smaller in size and have short calamus.

(*iii*) **Contours**. The contours are small feathers that cover the body and give it its shape or contour. They also resemble the quills. But their barbs are not so strongly joined and can be separated.

(*iv*) **Filoplumes**. The filoplumes occur beneath the contour feathers. They are extremely small in size. Each filoplume consists of a slender hair-like stem bearing a few free barbs at the tip. The filoplumes are seen in a plucked bird only.

(*v*) **Down Feathers.** The down feathers cover the newly hatched bird. Each consists of a short calamus and a short rachis bearing long flexible barbs.

The first digit of the hand, *i.e.*, the thumb or pollex, bears a tuft of small feathers. This is described as the **bastard wing** or **ala spuria.**

The feathers serve three important functions Those forming the wings act as the organs of flight. The body feathers provide a light insulating covering to prevent the loss of heat. The tail feathers form the braking and steering device.

Economic Importance. The pigeon forms an important laboratory animal, a nice pet and a good food.

The class Aves is divided into two sub-classes : **Archaeornithes** and **Neornithes**. The sub-class Archaeornithes includes the extinct birds like *Archaeopteryx* (Fig 39.10). The sub-class Neornithes includes the living birds. This is divided into three super-orders : **Palaeognathae** or **Ratitae, Impennae** and **Neognathae** or **Carinatae.**

Super-order (*i*) **Palaeognathae** It includes the flightless birds. The wings are greatly reduced or absent. The sternum is without a

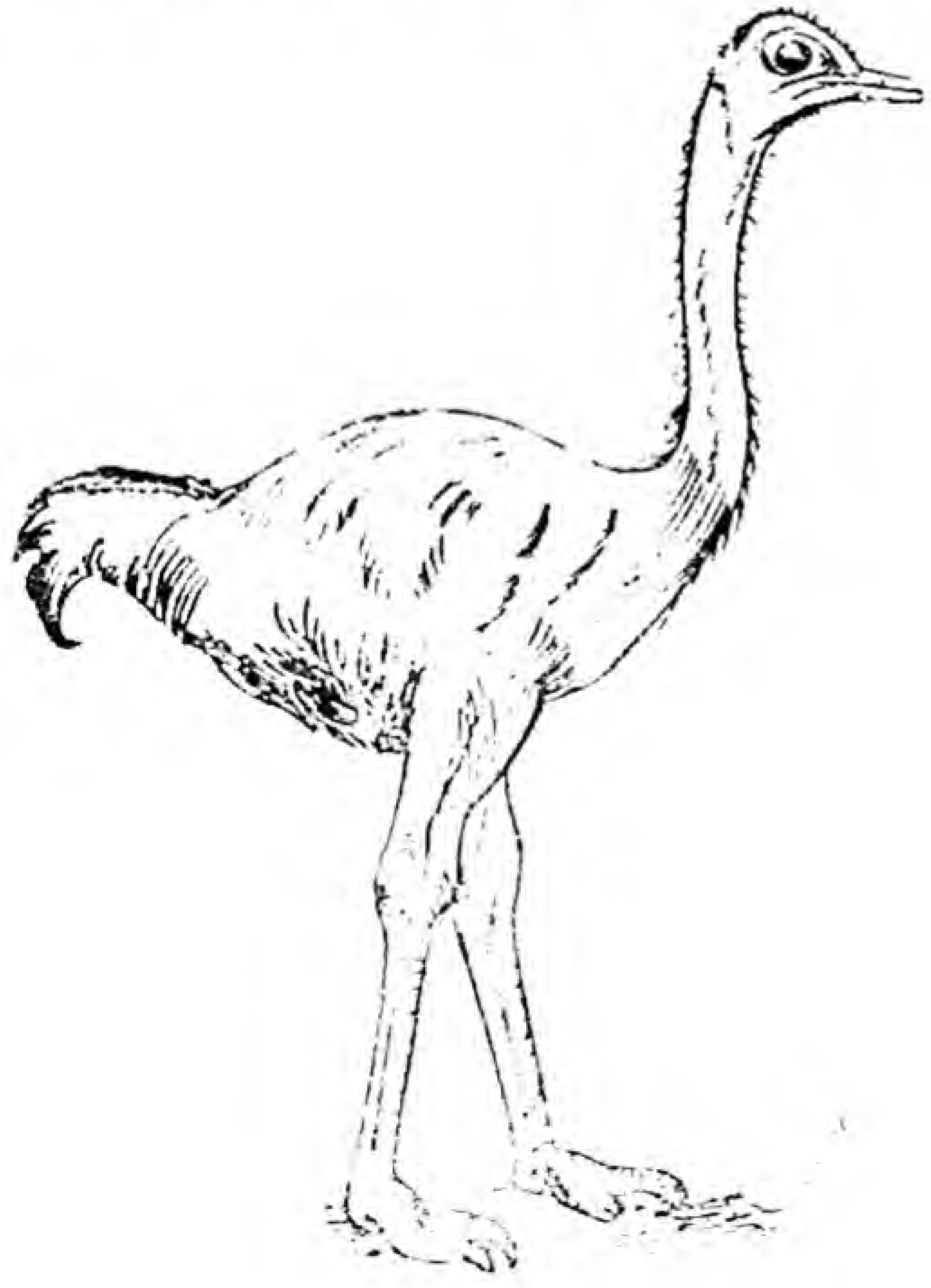


Fig. 36.33. The ostrich (*Struthio*)

Fig. 36.34. The Penguin

keel. There is rudimentary or no pygostyle or ploughshare bone at the end of the tail. The rectrices or tail feathers are absent or irregularly arranged. In the remaining feathers the barbs are free because there are no hooks on the barbules. The feathers are uniformly arranged in the adult so that there are no featherless spaces. There is usually no oil gland. The syrinx is absent. The male has a copulatory organ. The common flightless bird is *Ostrich*.

Ostrich (Fig. 36.33.) The ostrich, *struthis camelus*, is found in the deserts of Africa and Arabia. It is the largest bird measuring about 240 centimetres in height. Each foot has only two toes (3rd and 4th) which are covered with broad pads for running on sand. It is a gregarious bird and travels in groups of 3 to 20. It practises polygamy. One male looks after 4 to 5 females which lay eggs in the same nest. The nest consists only of a pit in the sand. The male incubates the eggs at night and covers them with warm sand by day. The bird is omnivorous.

Super-order (*ii*) **Impennae** It includes the penguins (Fig. 36.34.) which inhabit cold seas. They are most conspicuously adapted for water life. The fore-limbs or wings are modified into flippers which are used like oars for swimming. The feet are webbed to further assist in swimming. There is a layer of fat just beneath the skin to prevent the loss of heat from the body. The cold water can be entirely shaken off the feathers. The penguins are unable to fly. They sit upright on land. They feed on fishes.

Super-order (*iii*) **Neognathae (Carinatae)**. It includes the flying birds. These birds have well-developed wings. The sternum bears a median vertical keel. The pygostyle or ploughshare bone is formed by the fusion of a few terminal caudal vertebrae. The tail feathers or rectrices are present and are arranged round the pygostyle in a semicircle. In the feathers the barbs are united by hooks on the barbules. The body feathers are arranged in distinct feather-tracts separated by featherless spaces. The oil gland is usually present. The copulatory organ is lacking.

The birds of this division are divided into five categories : perching birds, birds of prey, game birds, wading birds and aquatic birds.

1. **Perching Birds**. These include the crows, sparrows, blue jays, parakeets, bulbuls, koels, pigeons and doves. They form more than half of the bird population. They are usually small in size but are the most highly organised among the Aves. Their feet have four toes and are adapted for grasping. The first toe or hallux is directed backwards and the others forwards. All the toes are at the same level and reach the ground. The birds perch on trees, poles, buildings, etc. All have call notes and a few are good singers. Their eggs are often coloured. The young birds are naked and are looked after by the parents.

Tailor-bird (Fig. 36.35). The tailor bird (*Orthotomus sutorius*) is known for its artistic nest. The nest is in a cup made of large green leaves stitched together with plant fibres. The bird punches holes along

the edges of leaves with its bill and passes fibres through the holes, expertly drawing the leaves into a cup to hold the nest.

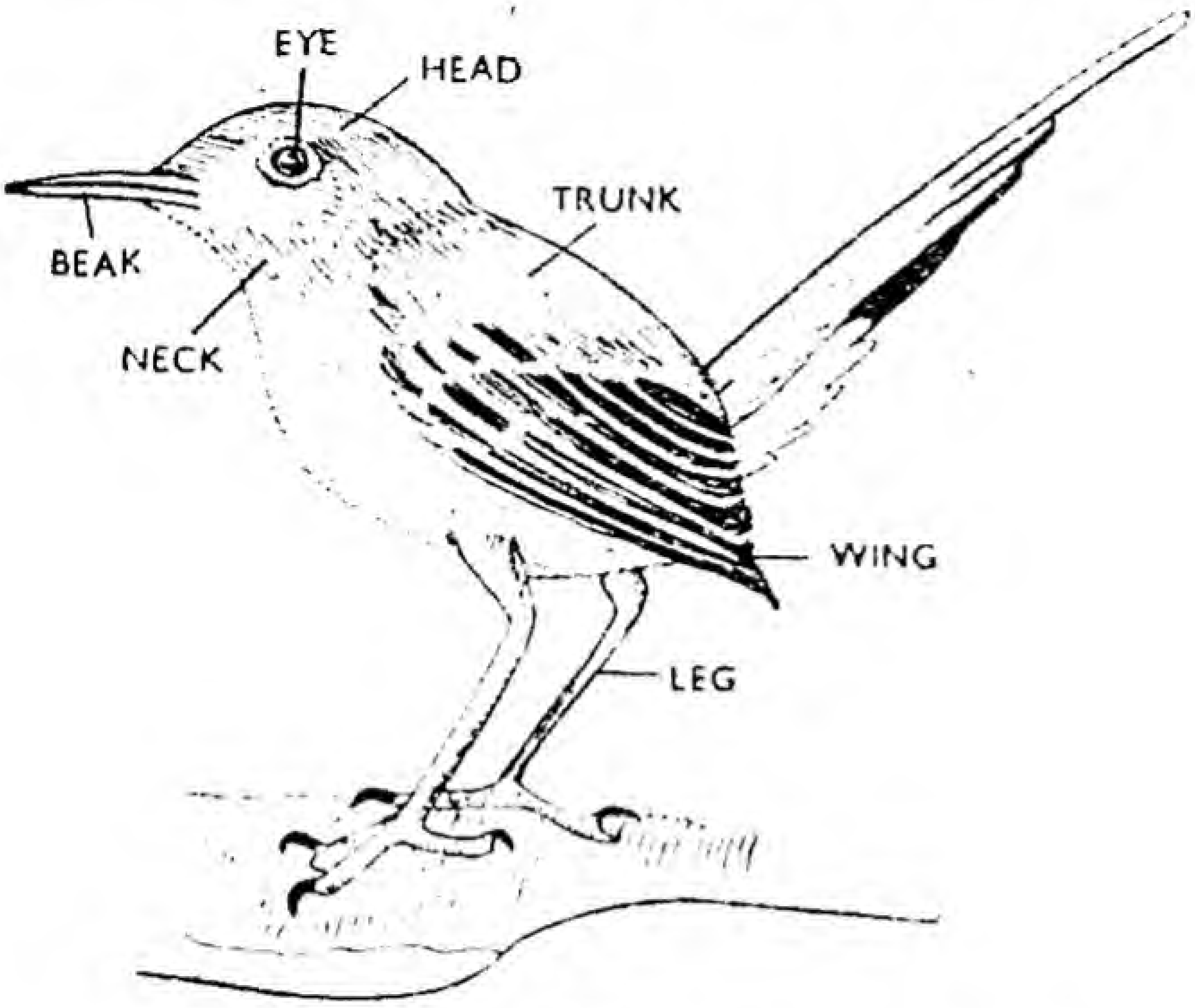


Fig. 36.35. Tailor Bird (*Orthotomus sutorius*)

Fig. 36.36. Parakeet (*Psittacula*)

Parakeet (Fig. 36.36). The parakeet or parrot (*Psittacula*) is found all over India, Pakistan, Ceylon and Burma. It has greenish plumage

Fig. 36.37. Owl (*Tyto alba*)

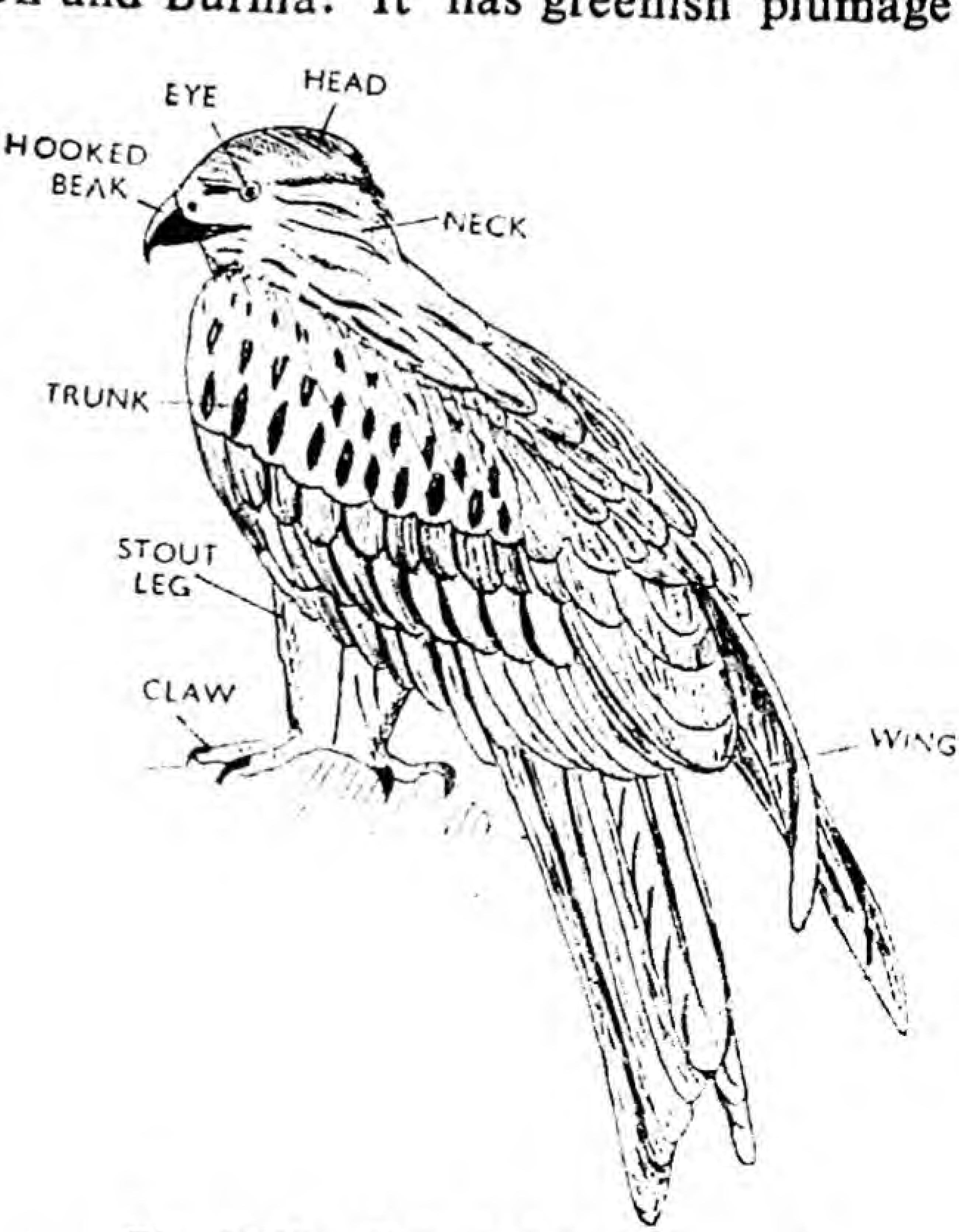


Fig. 36.38. Kite (*Milbus miagrans*)

with or without a black and pink collar round the short neck. The beak is very short, sharp-edged and stout, and consists of an arched maxilla movably ariculated to the skull and truncated mandible. There are sharp curved claws on the toes, two of which are directed backwards and two forwards. The tail is long and pointed. The parakeet feeds on fruits and grains.

2. Birds of Prey. These include the kites, vultures, eagles, hawks and owls. They are medium to large-sized birds. They are carnivorous and feed on small birds, mammals, frogs and lizards. They are well-adapted for hunting. They have powerful wings, keen eyesight, a stout hooked beak, and strong toes armed with sharp claws. The females are usually larger than the males. The female alone incubates the eggs but both the parents feed the young ones which are helpless on hatching.

Owl (Fig. 36.37). The barn owl (*Tyto alba*) is a nocturnal bird of prey common all over India. It has a large rounded head with a prominent ruff (collar) of stiff feathers round the flat face. The bird is golden-buff above and silky-white below. It has the keenest eyes in the animal kingdom. They are of large size, placed side by side and directed forwards. During the daytime, the pupil gets reduced to

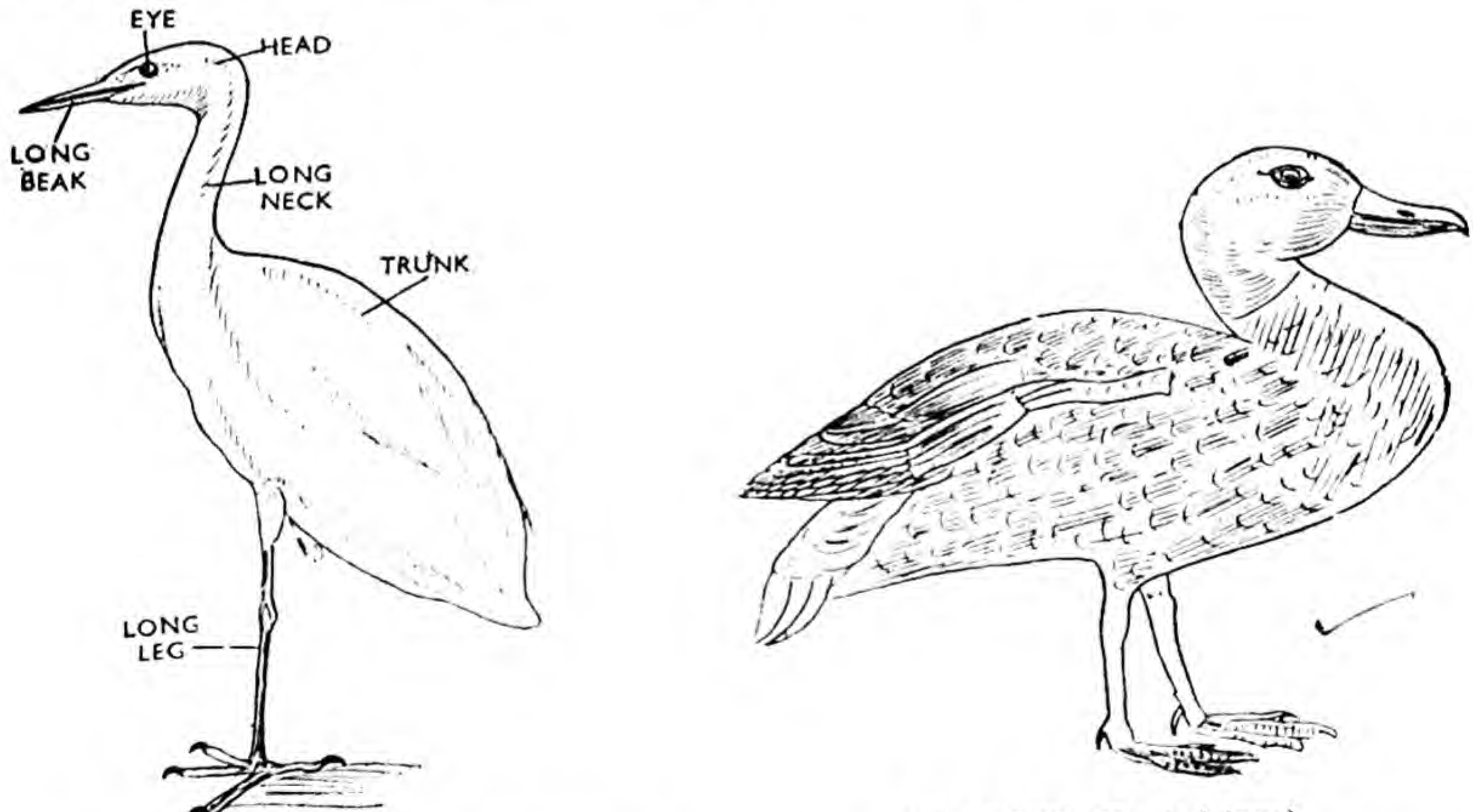


Fig. 36.39. Cattle egret (*Bubulcus*)

Fig. 36.40. Duck (*Anas*)

a mare dot and cannot see easily. At night, the pupil expands tremendously to enable the birds to see in the darkest forest. The bird is clothed in a soft fluffy plumage which renders it noiseless during flight. This enables it to reach the prey without being noticed. It has strong legs, stout claws and sharp curved beak for capturing and tearing the prey which consists of rats, hares, birds, frogs and insects. The hard indigestive remains of the food are vomitted out via mouth.

Kite (Fig. 36.38). The periah kite (*Milvus migrans*) is a large, dirty-brown, diurnal bird of prey. It has powerful legs, stout claws and sharp, hooked upper beak. Its tail is forked. It possesses a very keen eye-sight and a great power of flight. It often snatches eatables from the hands of children in the houses.

3. Game Birds. These include turkeys, fowls, quails, peacocks and partridges. They are large-sized birds except the quails As a rule, they are terrestrial but may rest or feed on the trees. They are poor fliers but good runners. They feed mainly on plant materials like tender shoots, seeds and fruits. Their feet are adapted for scratching and running. They yield palatable meat for which they are hunted. There is often a marked distinction between the two sexes, the males being more beautiful and larger. Many forms are polygamous. They make nests on the ground or small bushes. Many eggs are laid. The male birds take no part in nest building or caring for the young. The young at hatching have a covering of down feathers.

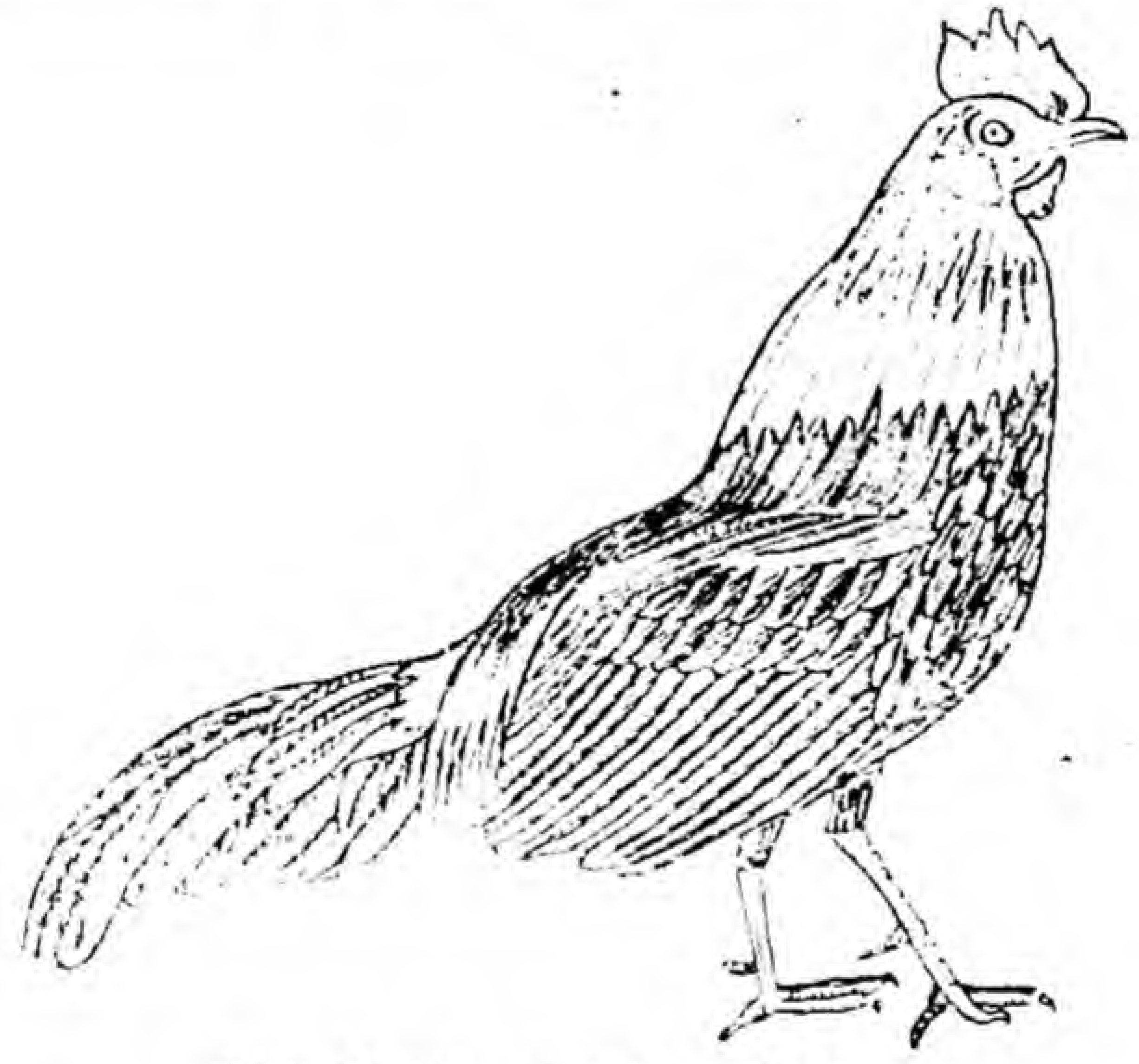


Fig. 36.41. Fowl (*Gallus*)

Fowl (Fig. 36.41). The fowl (*Gallus bankiva*), the red jungle fowl, is the origin of all the races of fowls. The fowl is essentially a terrestrial bird. It is gregarious in nature. It feeds on seeds, grains, tender shoots, etc. The male is larger and more beautifully coloured than the female. The male's head is further decorated with a crown-like fold of skin. There is a spur on each foot in the males. The female lays several eggs. The fowl is domesticated for meat and eggs.

Peafowl (Fig. 36.42). The pea fowl (*Pavo cristatus*) is a large game bird. The peacock has a brilliantly blue coloured body with a crest of feathers on the head, stout curved upper beak, long neck, fighting spurs on the legs, strong feet bearing sharp claws and a long train of numerous, gorgeous, erectile, ocellated tail coverts (not tail-quills). It enjoys the status of a national bird in India.

The peahen is smaller and comparatively dull coloured. It lacks spurs and train of tail coverts.

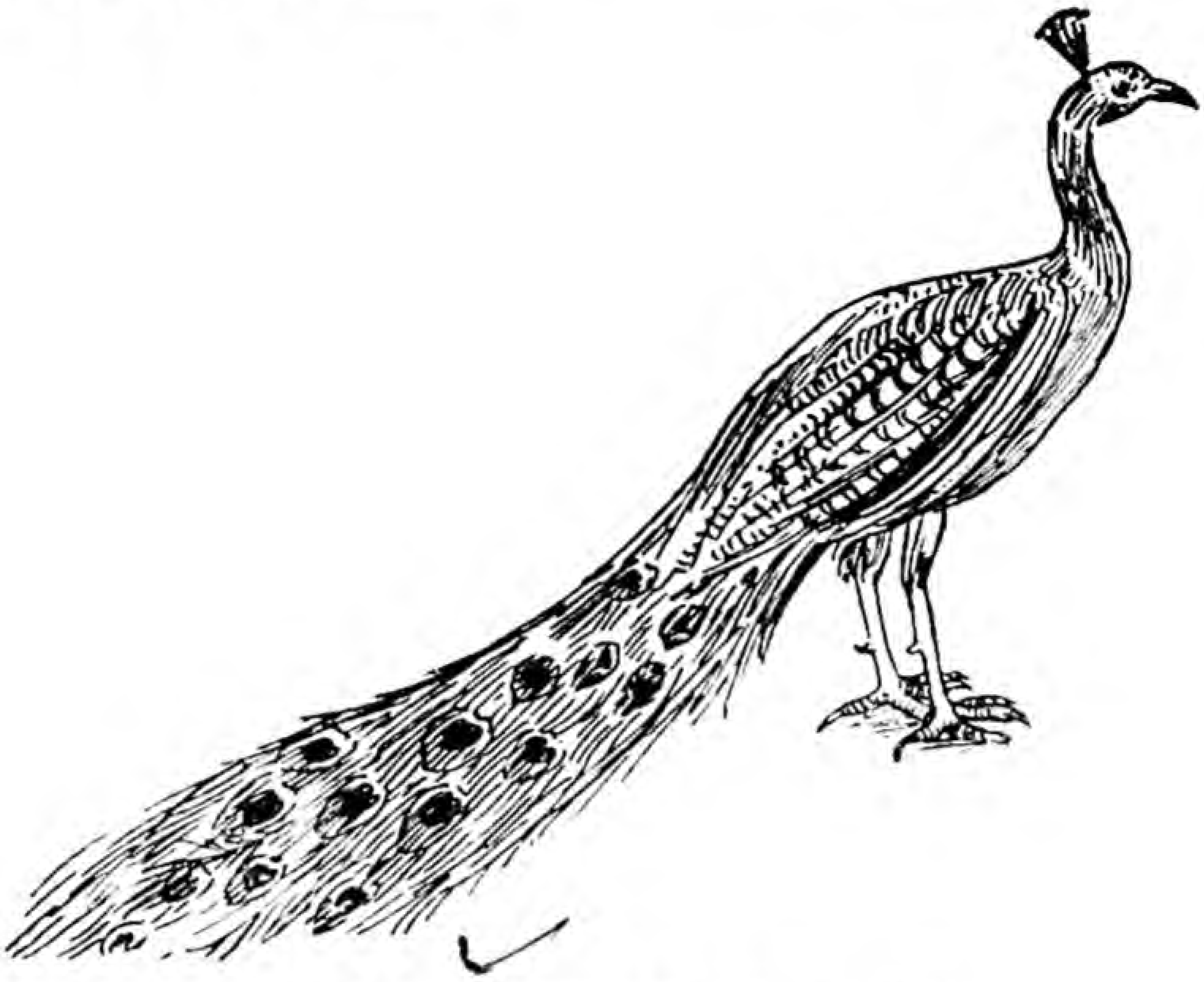


Fig. 36.42. Peacock (*Pavo cristatus*)

4. Wading Birds These include the herons, storks, egrets, etc. They feed in water but live on the trees. They have a long neck, long legs without web, a short tail and broad wings. All these features help them during feeding in water. Their food consists of fishes and other aquatic animals. They are usually gregarious birds.

Cattle Egret (Fig. 36.39). The cattle egret or 'bugla' (*Bubulcus*) inhabits marshy places. It has a pure white body with long legs and long neck. It is insectivorous. It is commonly seen in pastures along with grazing cattle. Movements of the cattle disturb the insects which are located and captured by the egrets.

5. Aquatic Birds. These include the ducks, geese, swans, and water-fowls. These birds are adapted to live and feed in water. They have a boat-shaped body, short legs, webbed toes and small tail for swimming. Their beak is often flat for digging prey from the mud. They are usually insectivorous. The young ones are covered with down feathers and can swim about soon after hatching.

Duck (Fig. 36.40). The duck (*Anas*) is found in the wild state in the Northern Hemisphere. It can swim and walk well The toes are fully webbed to aid in swimming and the beak is flat for digging prey from the mud. When feeding it does not dive but simply dips the head and neck so deep in water that the body becomes almost vertical. In this position, the tail stands erect in the air and the feet paddle to maintain the balance. The drake is polygamous. The nest is formed on the ground near water courses out of twigs and is lined with feathers pulled from mother's breast. There are 6-10 eggs in a clutch.

CLASS 6. MAMMALIA

The mammals are warm-blooded vertebrates primarily adapted for terrestrial life. The skin is covered with an epidermal exoskeleton of hair to conserve body heat. There are numerous glands in the skin, sebaceous and sweat glands in both the sexes and mammary glands in the famales.Mostly they are **quadrupeds**, having two pairs of pentadactyle limbs which are variously modified for walking, running, burrowing, climbing, swimming and flying. The digits end in claws, hoofs or nails. The skull bears two occipital condyles and has fewer bones. Each half of the lower jaw consists of a single bone, the **dentary**. The teeth are embedded in sockets of the jaw bones and are usually of various types : incisors, canines, premolars and molars. There are always seven **cervical vertebrae** irrespective of the size of the neck. The pectoral girdle is typically without a coracoid. There is a complete muscular partition, the **diaphragm**, between the thorax and abdomen. The cloaca is usually absent and there are separate outlets for the digestive and urinogenital systems. Several salivary glands open into the buccal cavity. The heart is four-chambered with two auricles and two ventricles. There is a single aortic arch which curves to the left side. The red blood corpuscles are rounded, biconcave and denucleated. The respiration is purely by lungs. The external ear has a meatus and pinna. The middle ear has three ossicles : malleus, incus and stapes. The brain is characterised by a large **cerebrum**, complicated **cerebellum,** four **optic lobes** and presence of **corpus callosum** connecting the two halves of the cerebrum. The males have copulatory organs. The testes usually descend into the scrotal sacs in the adult. The mammals are, as a rule, **viviparous.** The eggs are very small and without food. Fertilization is internal. There is intra-uterine development of the embryo accompanied by the formation of **placenta** for the metabolic exchange between the embryo and the mother. The young are nourished on milk for some time after birth and are brought up with a great care and love.

The class Mammalia is divided into two subclasses : **Prototheria** and **Theria**.

Sub-class 1. Prototheria (Monotremata). This sub-class includes the primitive mammals which lay large eggs with abundant yolk and hard shell. Ear lacks pinna. The mouth has horny beak. There is a common outlet, the cloacal aperture, for the digestive and urinogenital systems. Mammary glands are without teats or nipples. The pectoral girdle has a large coracoid. The platypus and spiny ant-eater are the examples.

Platypus (Fig. 36.43). The platypus (*Ornithorhynchus*) is found in the rivers and lakes of Australia and Tasmania, making nests or holes in the banks for resting. It is covered with a dense, dark-brown, woolly fur. The head is prolonged into a duck-like beak, lacks pinnae and bears small eyes and ear holes which can be closed simultaneously between two movable folds of skin. The limbs are short but have prominent hands and feet. There are on each limb five digits, all clawed and

webbed. The males have spurs on the inner side of the ankles. The spurs bear openings of poison glands whose secretion can kill small animals and can cause intense pain to man. The platypus feeds on worms, insects and shellfish. As a rule, a pair lives in one burrow, but, for laying eggs, the female makes a separate burrow where the males are not permitted. The eggs are incubated by the mother alone. There are no teats. The young suck from the fur which gets moistened from the glands.

Spiny Ant-eater (Fig. 36.44). The spiny ant-eater (*Tachyglossus*) is found in Australia, Tasmania, New-Guinea and neighbouring islands. It has a dense coat of hair all over. Some hair on the back are modified

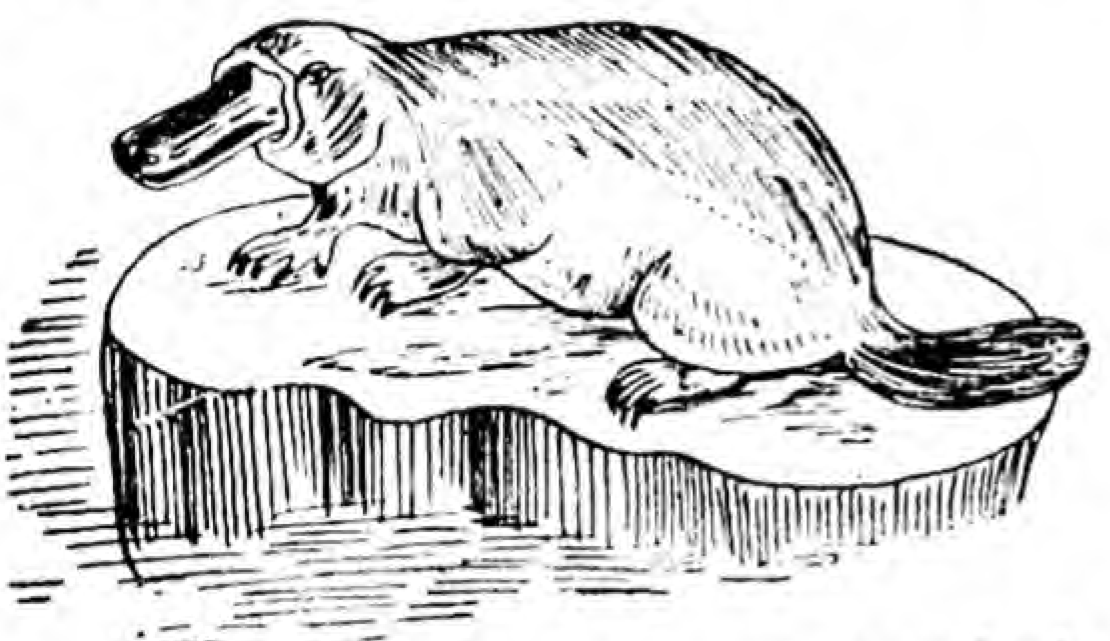


Fig 36.43. Platypus (*Ornithorhynchus*)

Fig. 36.44. Spiny ant-eater (*Tachyglossus*)

into short but sharp spines. The small head tapers into a hard naked beak which has a small rounded terminal mouth. The tongue is long, cylindrical, sticky and highly protrusible. The limbs are short but stout and bear strong claws on the digits. There is no tail.

The spiny ant-eater is nocturnal in habit. Its mode of feeding and defence are very interesting. It feeds on ants. The sticky tongue is thrust into ant-hill after it has been torn open with claws. The ants adhere to the tongue which is then withdrawn to swallow the food. On seeing an enemy, it quickly digs out a burrow in the ground using all the four limbs and gets into it, protruding a few spines out of the burrow.

The female lays eggs in a primitive pouch which she develops in the breeding season. The young hatch out in the pouch and live there till their spines start irritating the mother. They are then deposited in a burrow which they leave only after they become strong enough to look after themselves. In the pouch they suck mother's milk.

Sub-class 2 Theria. This sub-class includes the modern mammals which produce living young. Ear usually has pinna. Usually there is no cloaca and the digestive and urinogenital systems have separate outlets. Mammary glands open on teats. The coracoid is reduced. The sub-class Theria is divided into two infra-classes : **Metatheria** and **Eutheria**.

Infra-class 1. Metatheria (Marsupialia). It includes the Kangaroos. The young have a brief intra-uterine development and are born in very

imperfect condition. After birth they are nursed by the mother in a special pouch, the **marsupium**, present on the underside of the abdomen. The anus and urinogenital apertures are separate but are controlled by a common sphincter muscle.

Kangaroo (Fig. 36 45). The kangaroo (*Macropus*) inhabits Australia and Tasmania. It has a small head, a large body and a long tail. Its hind-limbs are much longer and more powerful than the fore-limbs. It walks on all the fours but runs on the hind limbs alone, balancing the body on the tail. The animal is herbivorous and gregarious. The young one is very helpless, blind, naked and only an inch long. The mother rears it in the marsupium where milk is forced into its mouth by the contraction of certain muscles of her belly as it is itself incapable of sucking.

Infra-class. 2 Eutheria (Placentalia). It includes the typical mammals. The young have a prolonged intra-uterine development during which they are nourished by a tιue placenta. With the result, the young are fairy well-developed at birth. The anus and the urino-genital aperture are quite distinct.

The intra-class Eutheria includes a number of orders of which the more common ones are : Insectivora, Primates, Chiroptera, Rodentia, Lagomorpha, Cetacea, Carnivora, Proboscidea, Perissodactyla, and Artiodactyla.

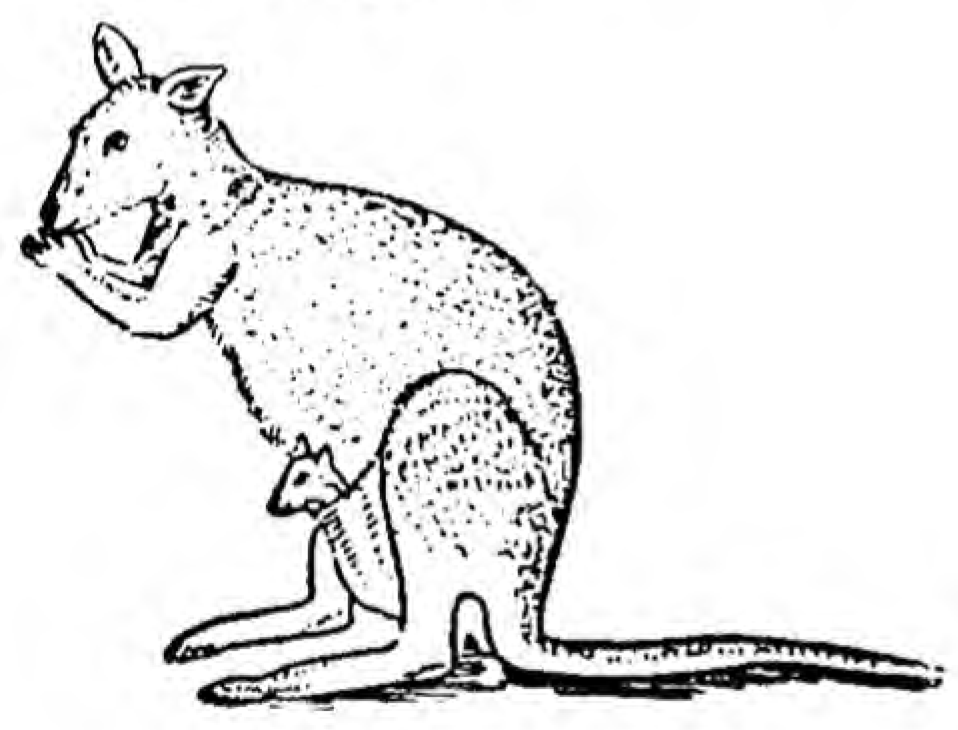


Fig. 36.45. Kangaroo (*Macropus*)

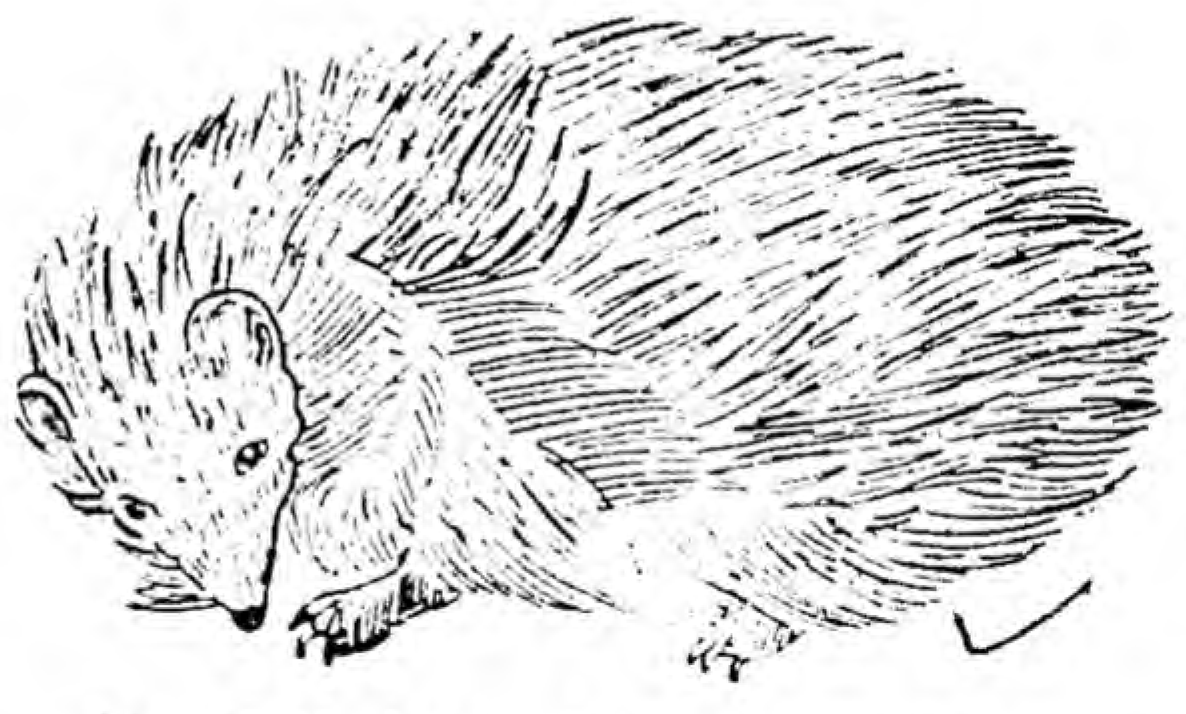


Fig. 36.46. Hedge-hog (*Hemiechinus*)

Order (*i*) **Insectivora**. It includes the hedge-hogs, moles and shrews. They are small mammals which feed on insects and worms. They have elongated snout, five-clawed digits on each foot, numerous teats and multiple births. The skin is usually covered with soft fur but sometimes with spines.

Hedge-hog (Fig. 36.46). The hedge-hog (*Hemiechinus*) is a small animal with globular body, pointed head, tiny stumplike tail and short limb, bearing clawed digits. The head, throat and belly are covered with fur while the rest of the body is armed with short, hard, erectile spines. It lives among bushes and feeds on insects, eggs, fruits, fungi, roots, etc. At the time of danger, it rolls itself into a ball.

Order (*ii*) **Primates.** It includes the most intelligent animals like the lemurs, loris, monkeys, apes and man. They have large, highly-convoluted cerebral hemispheres which incompletely or almost completely cover the cerebellum. Correlated with the greater development of the brain, the cranium is large and rounded with the foramen magnum on the lower side. They are plantigrade and have long limbs, each bearing five digits protected by nails. The first digit of each limb (pollex and hallux) can be brought opposite the remaining digits to make the hands and feet grasping organs. This is associated with the arboreal life to which most of the primates are adapted. The eyes are directed forwards to give binocular vision, *i.e.*, both eyes see the same object but from slightly different angles which provide depth to the images and enable the animal to judge distances correctly. The females have a single pair of teats which are located on the thorax. Usually a single young one is produced at a time and it gets a good deal of care and affection from the mother. The primates are omnivorous and gregarius.

Lemurs (Fig. 36.47). The lemurs are primitive primates as they have an elongated cranium, only slightly-convoluted cerebrum, incompletely overlapped cerebellum, partially-bony orbits and claws on the second toes. They are small furry animals having a fox-like face. They usually have a long tail which is not prehensile. They are solitary and lead an arboreal

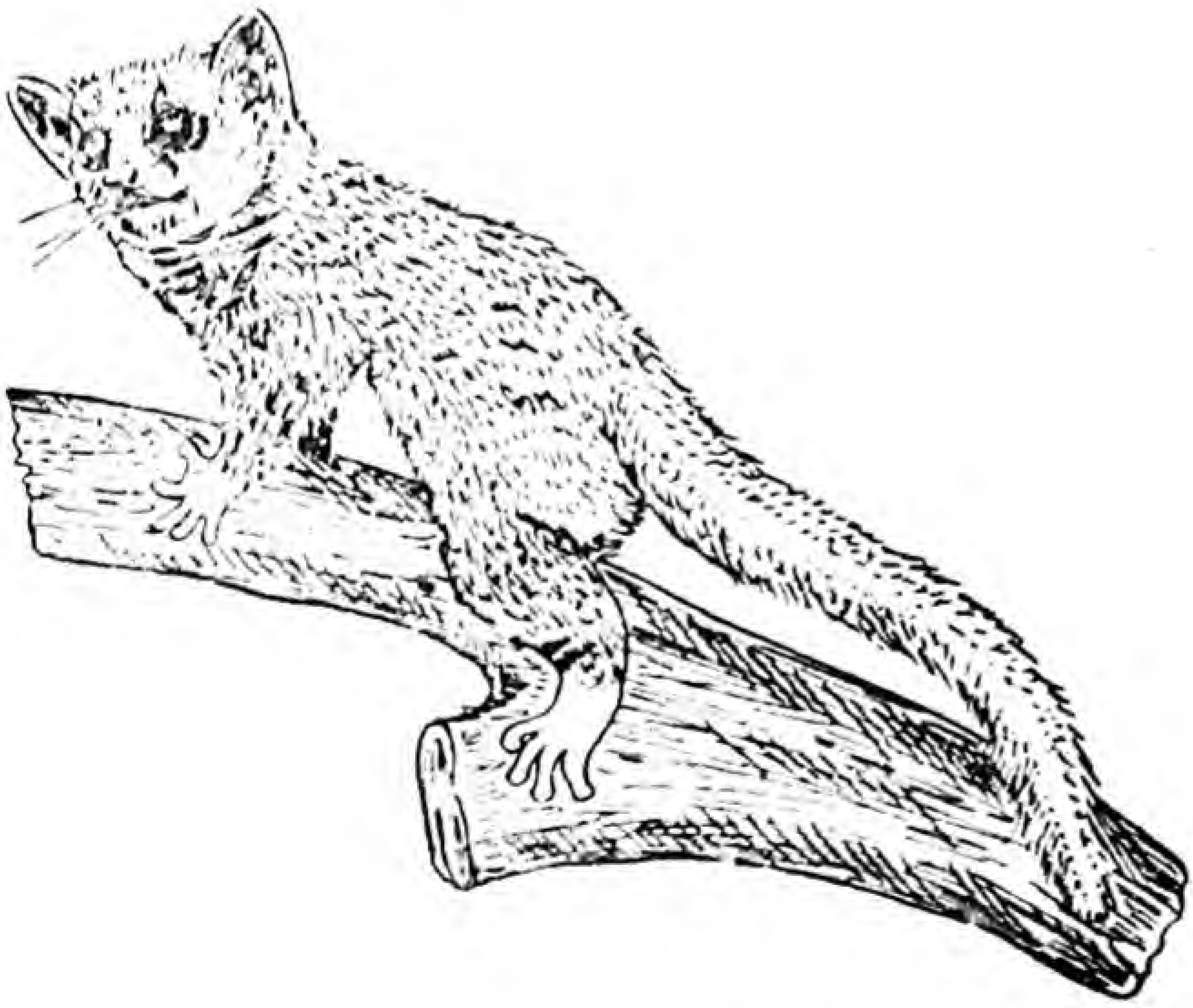


Fig. 36.47. Lemur (*Nycticebus*)

Fig. 36.48. Monkey (*Macaca*)

life in the tropical forests. They are either crepuscular or nocturnal and feed on fruits, leaves, eggs and small animals, They are found in Madagascar, Africa and South-eastern Asia to Philippines. **Nycticebus bengalensis** is an Indian lemur.

Loris (Fig. 36.49). The loris (*Loris*) is a small (about 8 inch long) tailless, slow-moving, nocturnal primate with a short, dense, soft fur,

large eyes and thin rounded ears. It is omnivorous, feeding on fruits, leaves, insects, eggs and birds. It is found in South India.

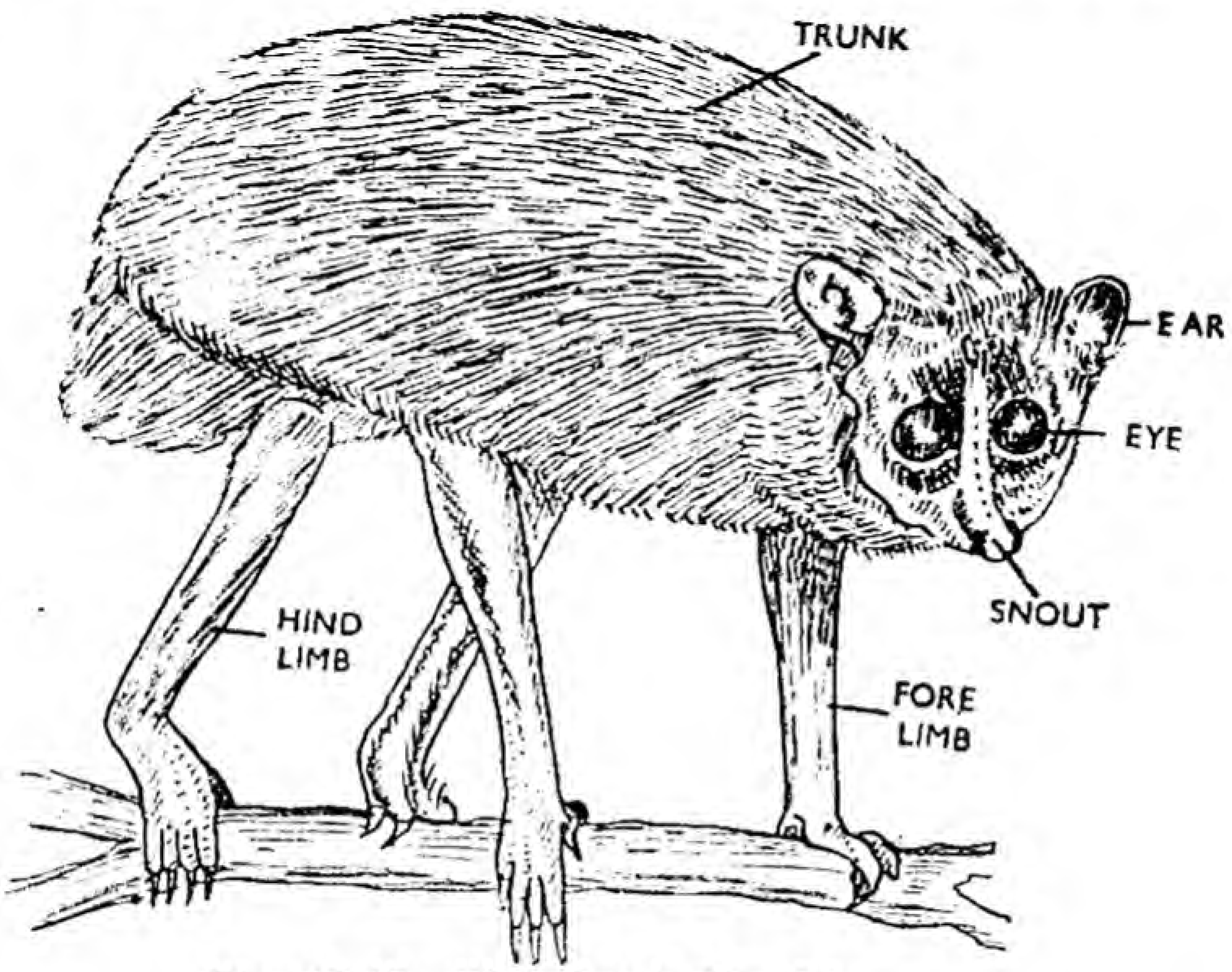


Fig. 36.49. Slow Loris (*Loris*)

Monkeys (Fig. 36.48). The monkeys have a tail and walk on all fours. They fall under two groups : the **old world monkey** and **new world monkeys**. Their differences are tabulated below :

TABLE 23

Old World Monkeys	New World Monkeys
1. Found in Asia and Africa.	1. Found in Central and South America.
2. Have cheek pouches.	2. Lack cheek pouches.
3. Possess a raised nose and a narrow internasal septum.	3. Possess a flat nose and a broad internasal septum.
4. Nostrils face downwards.	4. Nostrils face forwards.
5. Tail is not pre-hensile.	5. Tail is preh-ensile.
6. Have thick coloured pads, the **ischial callosities**, on the buttocks. They sit on these pads.	6. Lack ischial callosities.
7. Have two premolars.	7. Have three premolars.
8. Have bony external auditory meatus.	8. Lack bony external auditory meatus.
Example : *Macaca mulatta*-the rhesus or red faced monkey of North India.	Example : *Ateles*—the spider monkey.

Apes. (Figs. 36.50 and 36.51). The apes are the most man-like primates and include gibbons, orang-utans, chimpanzees and gorillas. They lack tail and cheek pouches. Mostly they are also without ischial callosities. They are chiefly arboreal, diurnal, gregarious and omnivorous. They have a loud voice and use it very often. They possess a

very characteristic mode of walking. The fore-limbs are considerably longer than the hind-limbs and both are adapted more for grasping than for walking. They walk on the outer edges of the feet and knuckles of the hands. This gives them a semi-erect, shuffling, bow-legged gait.

The **gibbons** are found in the central Himalayas, Burma, Indo-China, Java, Malaya, etc. They walk fully erect and have ischial callosities. The **orangutans** inhabit Borneo and Sumatra. The **chimpanzees** (Fig. 36.50) are found in Africa. They have large ears and lips. There is a prominent ridge on the eyes. The chin is quite clear. The gorillas (Fig. 36.51) live in Africa. Their ears and lips are small. There is a prominent ridge on the eyes. The chin is absent.

Fig. 36.50. Chimpanzee (*Pan troglodytes*)

Fig. 36.51. Gorilla (*Gorilla*)

Man. The man (*Homo sapiens*) is the most highly-developed primate. He has dominated all life with his superior brain and intelligence. He is a terrestrial, highly-gregarious, omnivorous primate who usually takes cooked food. He has a bipedal locomotion and walks thoroughly erect after infancy. He has long, evergrowing hair on the head and short, sparsely arranged hair on the body. He possesses a broad forehead, almost a flat face, and a distinct chin. The arms are shorter than the legs. The hand forms a perfect grasping organ. The greater toe or hallux is very large and unopposable. He alone has a language and speech. He has penetrated all parts of the world and is now attempting to conquer other planets.

Order (*iii*) **Chiroptera.** It includes the bats. They are the only mammals with true flight and this is mainly responsible for their world-wide distribution. Their organs of flight are the lateral extension of the skin, the **patagia**, supported by the fore-limbs and their greatly elongated digits except the first. The patagia may include the hind-limbs and tail also in them. The hind-limbs are relatively short and weak with the knees turned backwards like the elbows. This makes the bats helpless on the ground. All the five digits of the hind-limb and

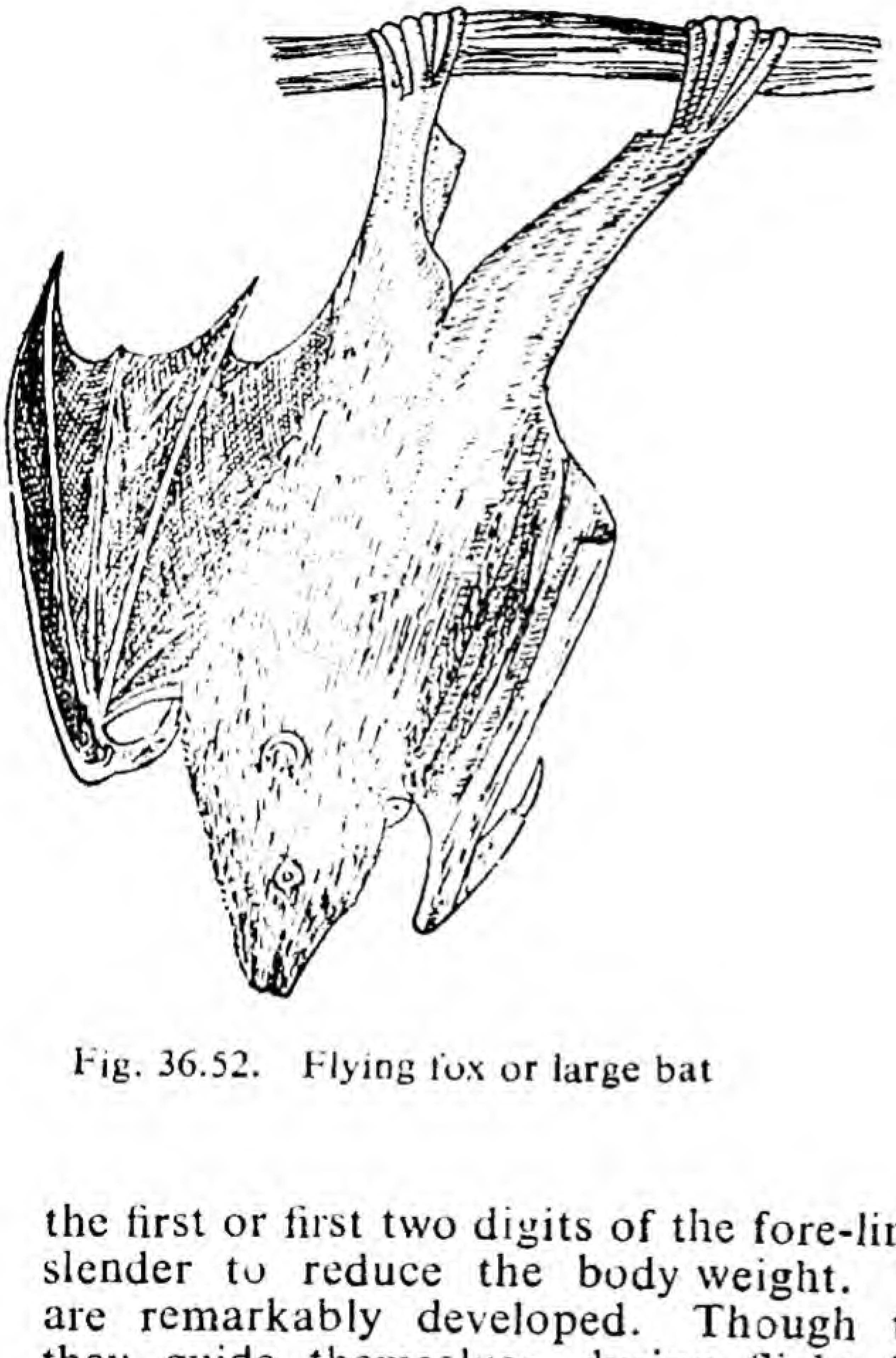


Fig. 36.52. Flying fox or large bat

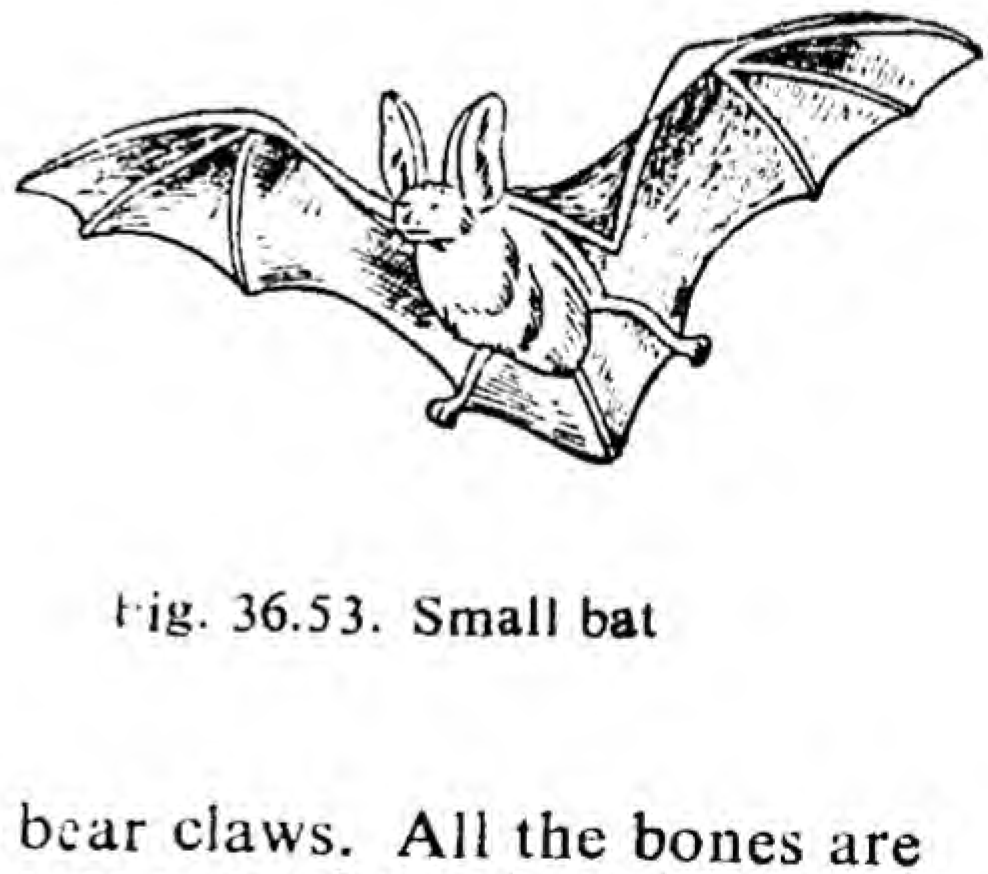


Fig. 36.53. Small bat

the first or first two digits of the fore-limb bear claws. All the bones are slender to reduce the body weight. The senses of touch and hearing are remarkably developed. Though the bats have eyes and see well, they guide themselves during flight by the principle of radar. They produce supersonic sounds which are thrown back from the objects in the way and are perceived by the ears. The penis contains a bone in it. Usually there are only two mammae which lie on the throax. They produce only one or sometimes two young ones at birth. They are nocturnal animals. They spend the day hanging head downwards from the various objects by the claws of one or both the feet.

The bats are of two types : small bats and large bats or flying foxes. Their differences are tabulated below---

TABLE 24

Small Bats	Large Bats
1. Feed on insects.	1. Feed on fruits.
2. Bear a claw only on the first digit of the fore-limb.	2. Bear claws on the first two digits of the fore-limb.
3. Have a tail.	3. Lack a tail.
4. Possess a short snout.	4. Possess an elongated fom-like snout.
5. External nares may be surrounded by peculiar leaf-like appendages, the **nose leaves.**	5. External nares are without nose leaves.
6. Pinna has small lobes, the **earlets,** inside it.	6. Pinna is without ear lets.
7. Interfemoral membrane is very large and includes tail.	7. Inter femoral membrane is very narrow.
8. Inhabit houses in both the hemispheres.	8. Inhabit trees in deserted areas in the old world.
Example : *Scotophilus* of India.	Expamle : *Pteropus* of India.

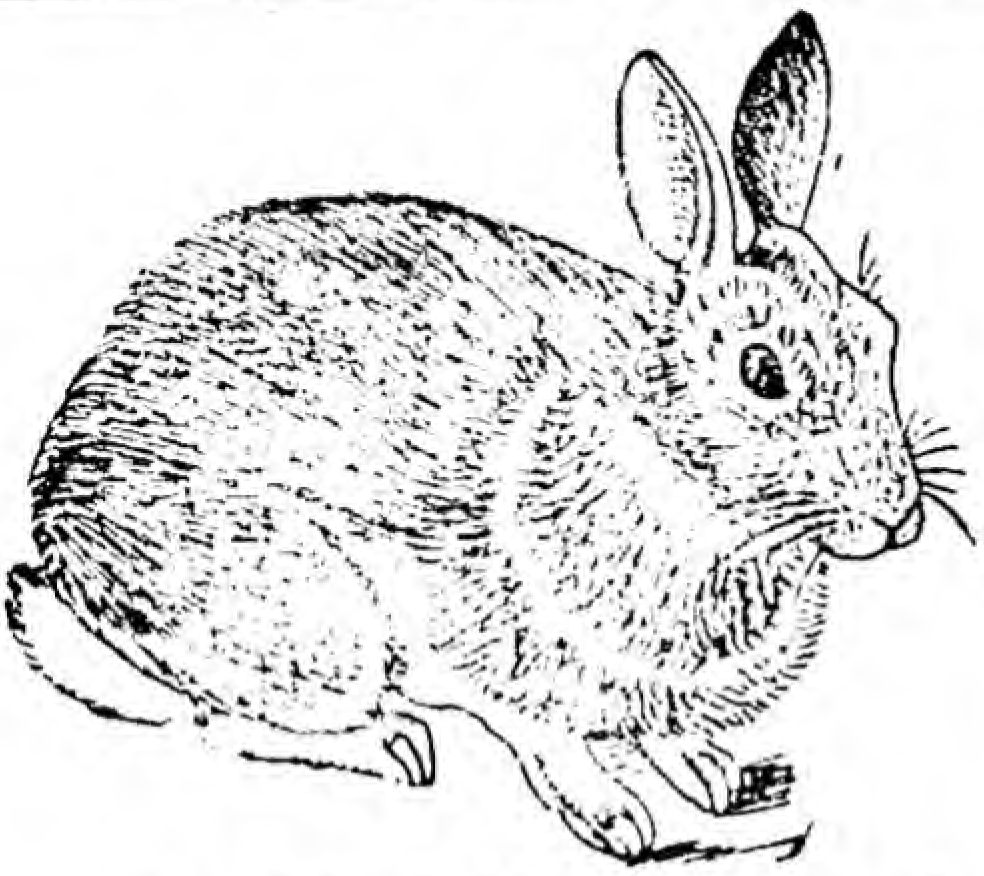
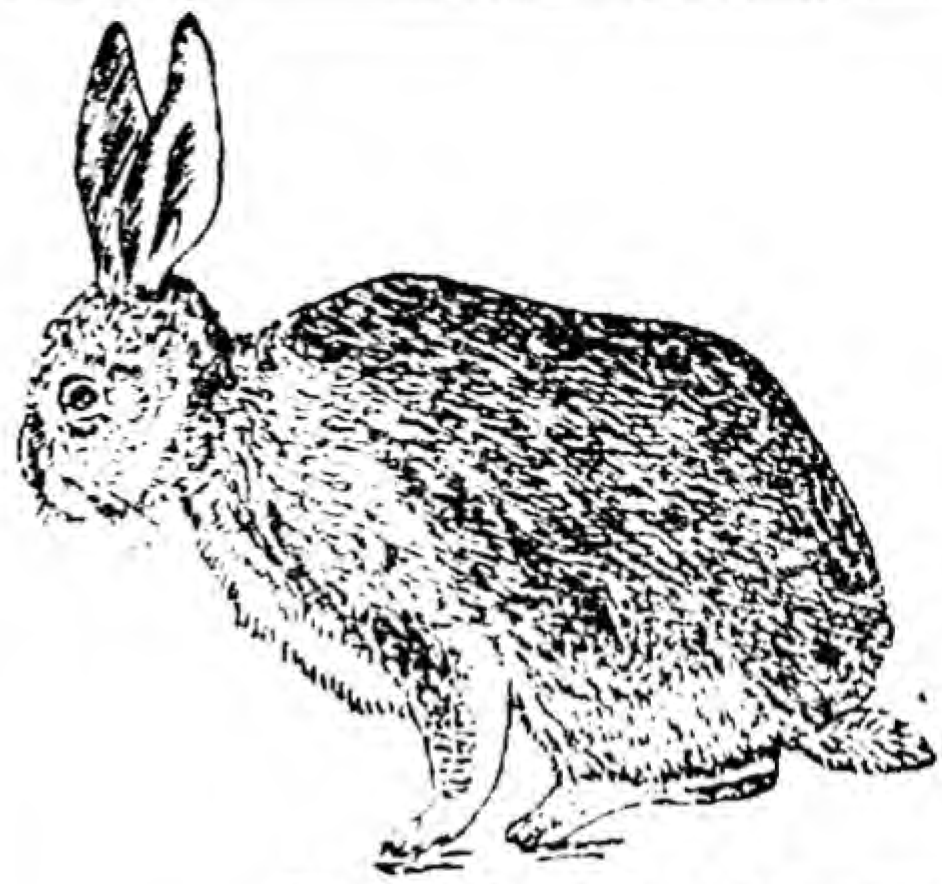
Order (*iv*) **Rodentia**. It includes the rats, mice, squirrels, porcupines, beavers and Guinea pigs. They are small animals typically herbivorous in diet. They gnaw their food in a characteristic manner. They have a pair of sharp chisel-shaped incisors in each jaw. The canine teeth are absent. There is a toothless space, the diastema, between the incisors and premolars. The digits bear claws. The skin is covered with fine fur. The mode of progression is plantigrade or semiplantigrade. The testes are abdominal or inguinal. They are prolific breeders and produce several young ones at a time. They have numerous mammae. They are found all over the world.

Rat (Fig. 36.46). The house rat (*Rattus rattus*) is a serious domestic pest. It is nocturnal in habit. Its body is greyish black above and dark-ashy below. It measures about 18 cm. from snout to anus. The tail is about 20 cm. long, tapering and covered by epidermal scales.

Mouse. The house mouse (*Mus musculus*) is only 8 cm. long from snout to anus and its tail is 10 cm. long. Body is dusky reddish-brown above and paler below.

Order (*v*) **Lagomorpha.** It includes rabbits (Fig. 36.54) and hares (Fig. 36.55). They possess two pairs of incisors in the upper jaw. The tail is comparatively short.

TABLE 25
Differences between Rabbit and Hare.

The Rabbit	The Hare
 Fig. 36.54. Rabbit (*Oryctolagus*)	 Fig. 36.55. Hare (*Lepus*)
1. It is a fossorial animal living in a permanent home which is a burrow of its own excavation in the ground	1. It is a nomad staying temporarily at some sheltered spot behind a stone or under a bush.
2. The pinna of the ear is comparatively short and is without a black tip	2. The pinna is longer and has a black tip.
3. The hind-limbs are also shorter.	3. The hind-limbs are longer.
4. In the fore-limb the radius is shorter than the humerus and the claws are very stout for digging.	4. In the fore-limb the radius is longer than the humerus and the claws are not so strong as in the rabbit.
5. It is gregarious in nature.	5. It is solitary in nature.
6. The young are weak, naked and blind at birth.	6. The young are quite strong, have fur and open eyes at birth.
7. It is a good runner but can run swiftly only for a short distance For this reason it never ventures far from its burrow.	7. It is also a good runner and can keep up a great speed for a long distance.
8. The danger signal is a sound produced by thumping the ground with the hind-limbs.	8. The danger singal is a sound produced by grinding the incisors against one another.
9. The anterior incisors of the upper jaw are marked by a vertical groove on the outer surface.	9. There is no such groove.
10. The skull has a distinct interparietal bone.	10. The interparietal is fused with the supraoccipital in the skull.
11. It forms a good domestic pet.	11. It does not thrive in captivity.
12. It usually feeds at dusk and dawn—crepuscular.	12. It usually feeds at night—nocturnal.

Order (*vi*) **Cetacea**. It includes the whales, dolphins and porpoises. These are the most highly modified mammals. They are medium to very large-sized animals wonderfully adapted for aquatic life. The body is fish-like in appearance. It is covered with a smooth skin which lacks hair except a few near the mouth. There are no sweat and oil glands. There is a thick layer of fat, the **blubber**, beneath the skin to prevent

the loss of body heat into the surrounding cold water. The fore-limbs are modified into paddle-like flippers. The hind-limbs have disappeared. The tail is dorso-ventrally flattened and ends in two horizontal flaps, the **flukes**. The tail is moved up and down for swimming. The ear lacks pinna and has a minute opening. The eyes are very small, without nictitating membrane and lie near the angles of the mouth. The external nares, one or two, are placed far back on the top of the head. The teeth, if present, are all alike and lack enamel. The bones are spongy The females have only two mammae and produce a single or at the most two young ones at a time. The cetaceans are carnivorous and mostly gregarious. They are found all over the world.

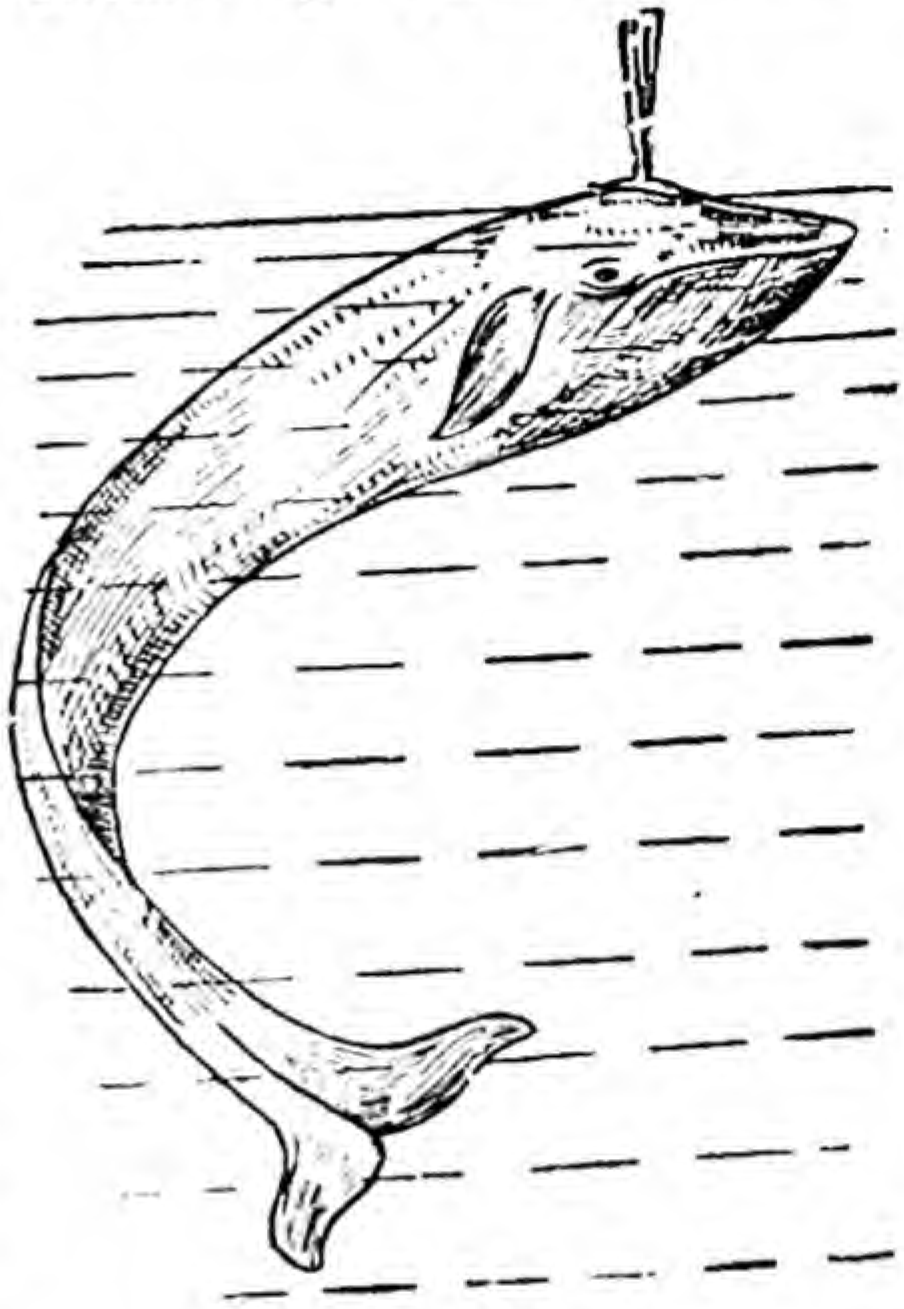


Fig. 36.56. Whale

The whales (Fig. 36.56.) are strong and fast-swimmers. They can dive for several minutes. When they come to the surface for breathing, the warm moist air from the lungs is blown out with a great force. It condenses into a thick cloud with cooler air outside. This cloud may ascend to a height of 365 centimetres and can be seen from a long distance. This phenomenon is called blowing or spouting. The whale at once dies if stranded on the shore because the huge body exerts a tremendous pressure on the internal organs which are consequently **crushed**. The whales are hunted for oil from their blubber.

Order (*vii*) **Carnivora**. It includes the dogs, jackals, wolves, foxes, cats, leopards, tigers, lions, bears, mongooses, seals, etc. They are very agile, bold and ferocious animals. They, as a rule, feed on the flesh of other animals. A few, however, are omnivorous or even herbivorous. They have sharp well-developed claws, strong projecting canines and powerful jaws, heavy musculature—all to capture, kill and tear the prey. The incisors are small and are of little use. The premolars and molars are also mainly adapted for cutting so that the food is cut up into small morsels to be swallowed without mastication. The mammae are abdominal.

The order Carnivora has 2 sub-orders : **Fissipedia** and **Pinnipedia**.

Sub-order (*i*) **Fissipedia**. The Fissipedia are terrestrial carnivores. The digits are separate and bear claws. The last premolar in the upper jaw and the first molar in the lower jaw bite on each other like a pair of scissors for cutting the flesh. These two teeth are called the **carnassial** teeth. The Fissipedia are found all over the world.

Cats, Lions (Fig. 36.57), **Tigers, Leopards**. The cats, lions, tigers and leopards (*Felise* or *Panthera*) walk on the toes (digitigrade) and have retractile claws. They stalk their prey and then jump on them with a sudden fast run. They are unable to cover long distance at a high speed. The body is striped in the tigers and spotted in the leopards. It is neither striped nor spotted in the lions.

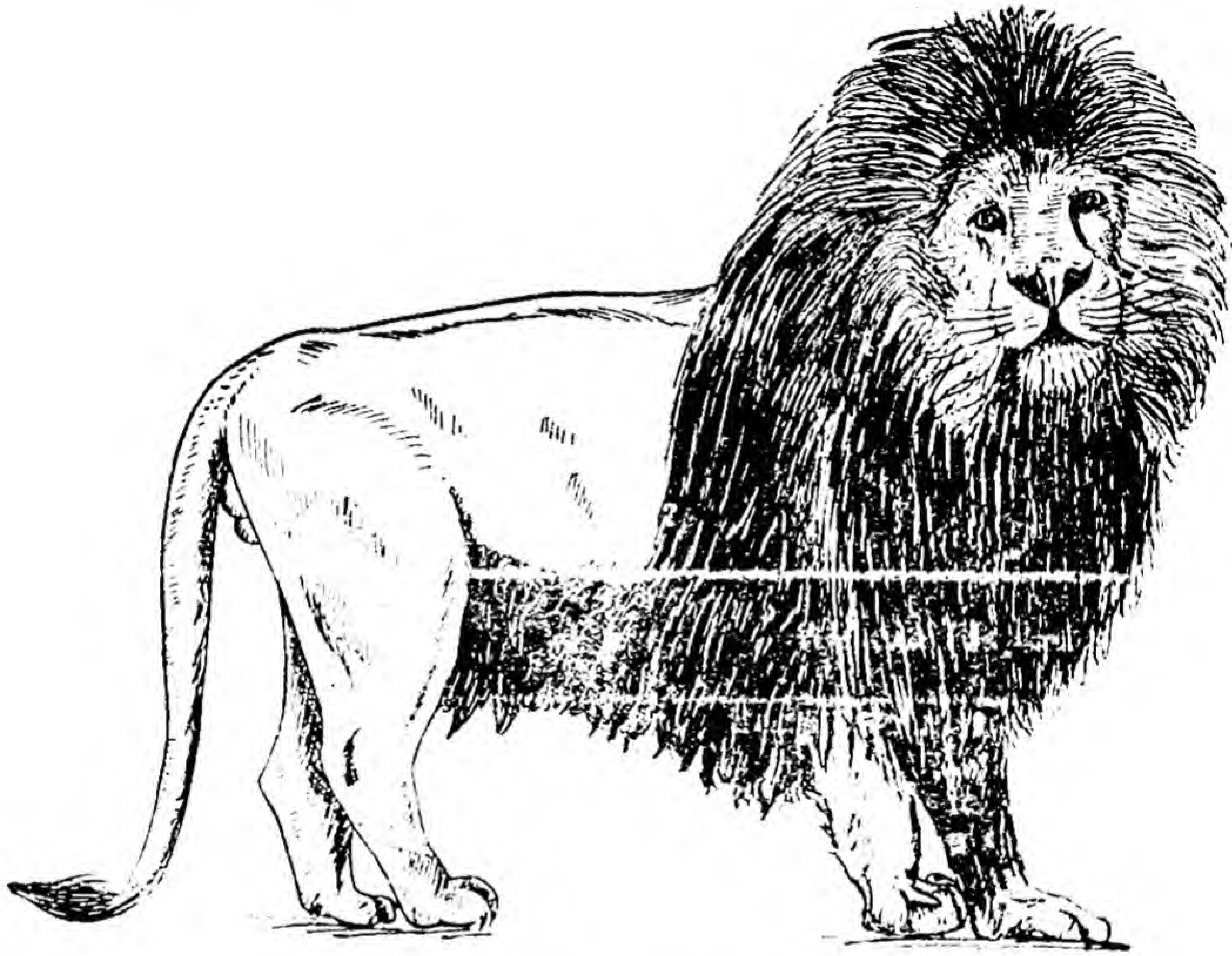


Fig. 36.57. Lion (*Felis leo*)

Dogs, Wolves (Fig 36.58). **Jackals**. The dogs, wolves and jackals (*Canis*) are also digitigrade but have non-retractile claws. They run their prey down in a long chase.

Bears. The bears (*Ursus*) possess a thick clumsy body with rudimentary tail and coarse hair of black or brown colour. The bears walk on the soles of the feet (plantigrade) and have non-retractile claws. Their gait is awkward. They are omnivorous in diet.

Mongoose. The mongoose (*Herpestes*) has dog-like, non-retractile claws. It can erect its fur when excited and can kill a snake. It feeds on rats, frogs and snakes.

Sub-order (*ii*) **Pinnipedia**. The pinnipedia are aquatic carnivores. They have fusiform body, reduced or no external ear, paddle-like limbs and a short tail. The digits are enclosed in the web. The Pinnipedia are gregarious animals. They feed on fish, molluscs and crustaceans. They

breed on land. They inhabit the coastal seas of Temperate and Arctic regions. The common examples of the sub-order are : seals (Fig. 36.59), walruses and sea-lions.

Order (*viii*) **Froboscidea**. It includes the elephants (Fig. 36.60) which are the largest terrestrial animals. They are characterised by a large head, short neck, small eyes, broad fan-like ears, huge trunk, thick pillar-like legs and a small tail. The snout and the upper lip are prolonged into

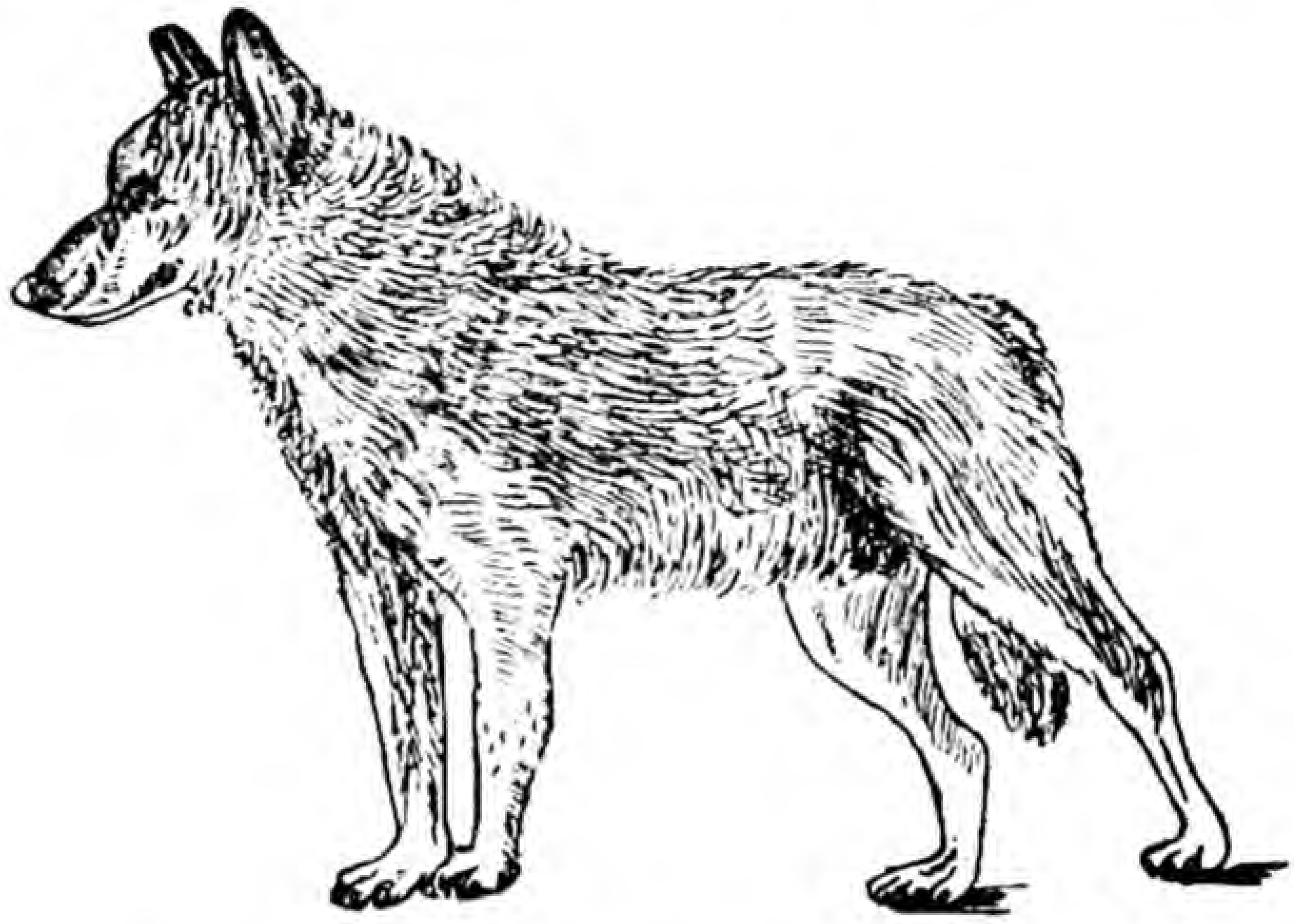


Fig. 36.58. Wolf (*Canis lupus*)

a long muscular prehensile proboscis or trunk. The proboscis contains nasal passages and bears external nares at its lower free tip. The proboscis serves to gather and put food into the mouth. It also serves to take water for which it is first filled and then emtipied into the mouth. The skin is very thick and loose with scanty hair. The upper jaw bears only two incisors, which are greatly-enlarged to form the tusks. The tusks are mainly formed of ivory, the enamel being restricted only to the

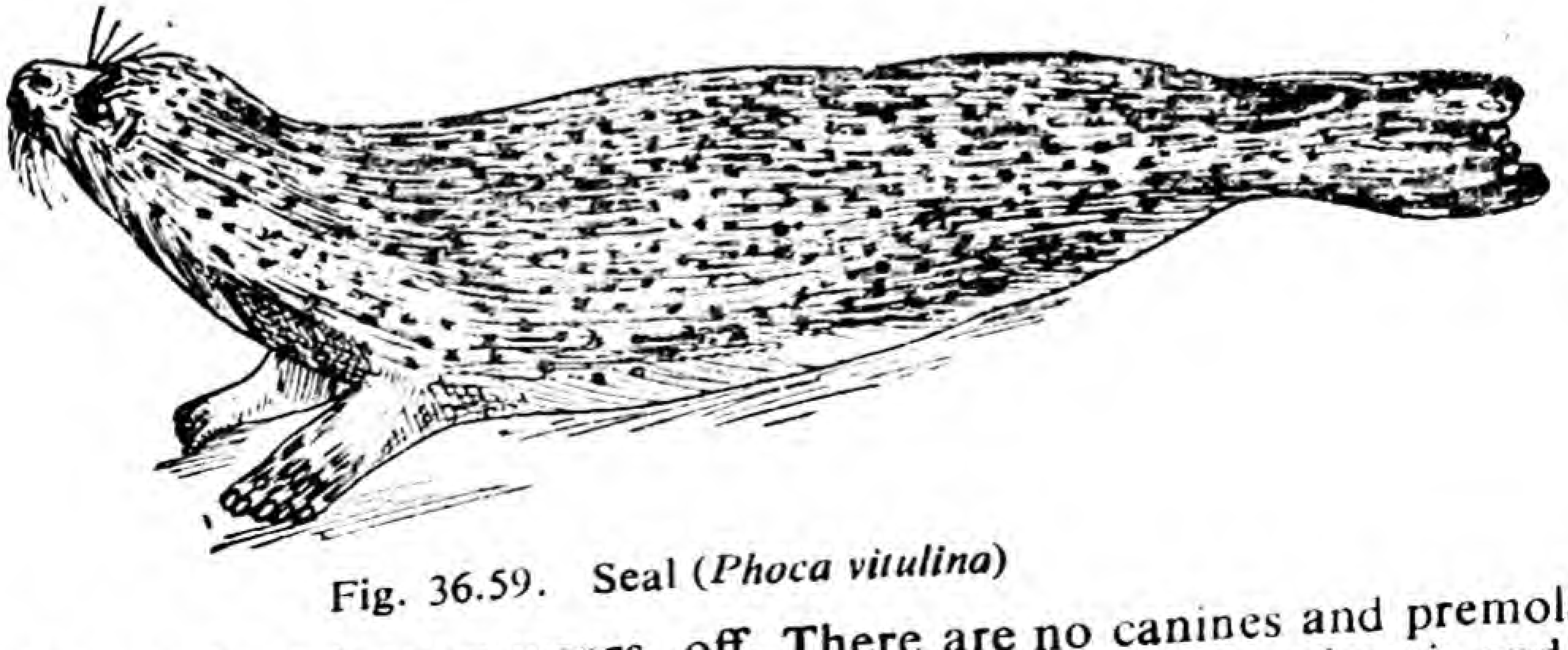


Fig. 36.59. Seal (*Phoca vitulina*)

apex from where it soon wears off. There are no canines and premolars. The skull is very large and powerful to support the proboscis and the tusks. The skull bones enclose air spaces to reduce the weight of the huge head. The limbs are pentadactyle but short and stout digits are

embedded in a common integument so that they are not distinct externally. Each digit ends in a small nail-like hoof. There is a large elastic cushion beneath the digits. The mode of progression is digitigrade, the cushions supporting the weight of the body. The gait of the elephant is peculiar and proverbial as the limbs do not bend at the elbows and knees during walking. The females have a single pair of mammae which are on the thorax. The elephants inhabit forests and tall grasses in India and Africa. They are herbivorous in diet and gregarious in habit, roaming about in herds of 10 to 100. In spite of their huge size, the elephants can be easily caught and tamed for use as beasts of burden.

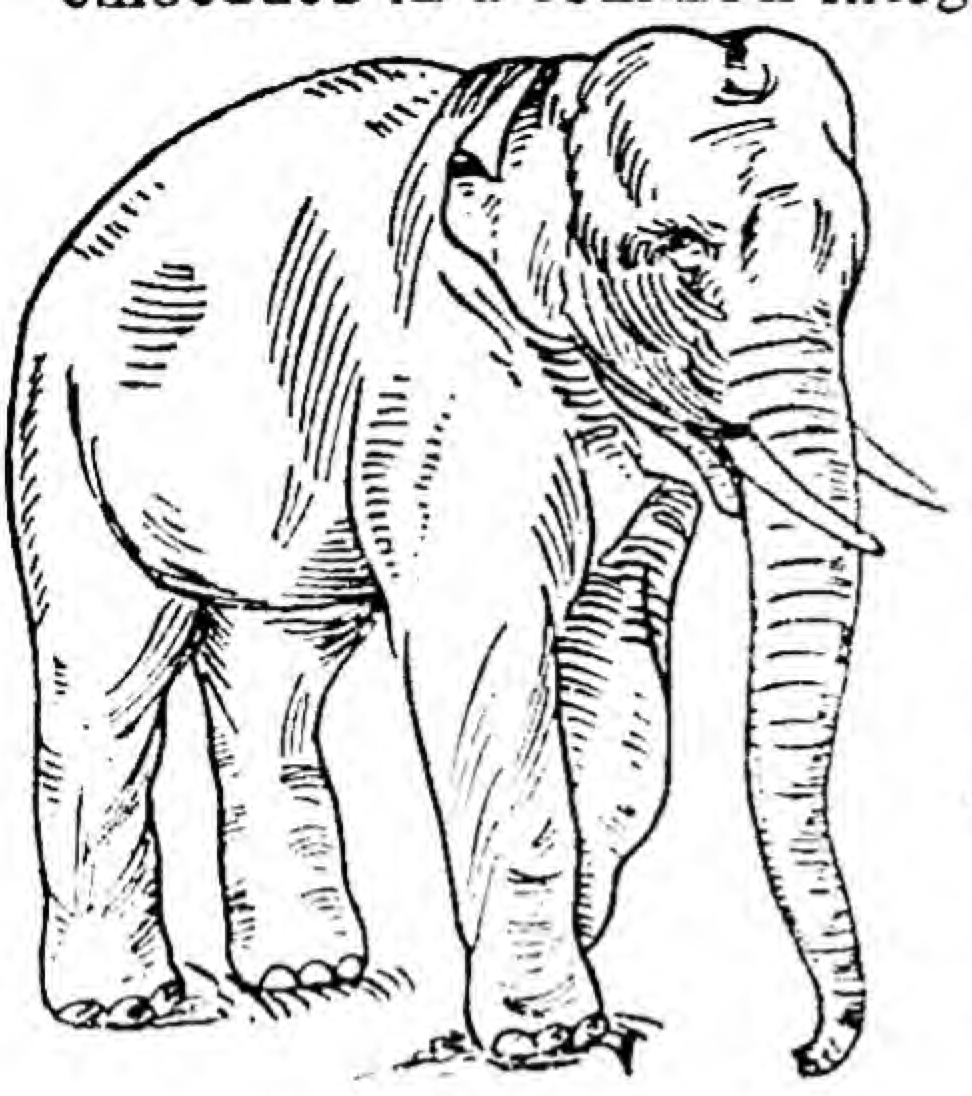


Fig. 36.60. Indian elephant (*Elephas indicus*)

TABLE 26

Indian Elephant	African Elephant
1. Body 3 metres high.	1. Body 3·45 metres high.
2. Tusks 3·3 metres long and occur in both the sexes.	2. Tusks 2·7 metres long and occur only in the males.
3. Pinnae comparatively short.	3. Pinnae very large, cover shoulders.
4. Back is arched.	4. Back is depressed.

Order (*ix*) **Perissodactyla**. It includes the horses, asses, zebras, rhinoceroses, tapirs, etc. These are terrestrial and herbivorous mammals. They have long limbs adapted for swift running. They have odd number of digits. The main axis of the limb that divides it into two halves, passes through the third digit which is larger than the others. The digits are enclosed in cornified hoofs. The mode of progression is unguligrade, *i.e.* the animal walks on the tips of the digits with the heels raised from the ground. Consequently, there are three segments in the limb instead of two as in other vertebrates. There are no horns on the head.

Rhinoceros (Fig. 36.61). The rhinoceros (*Rhinoceros unicornis*) is found in South Eastern Asia and Africa. It is nocturnal and herbivorous. It is a large, heavy animal with comparatively short legs. Each leg

bears three toes furnished with broad hoofs. The large elongated head bears one or two horns along the middle line of the anterior end. The horns grow from the skin and have no connection with the bones of the skull. The skin is very thick, naked or sparsely hairy, and is often deeply folded on certain parts of the body. The tail is thin and moderately long. The rhinoceros normally avoids man but if brought to bay proves very fierce and dangerous.

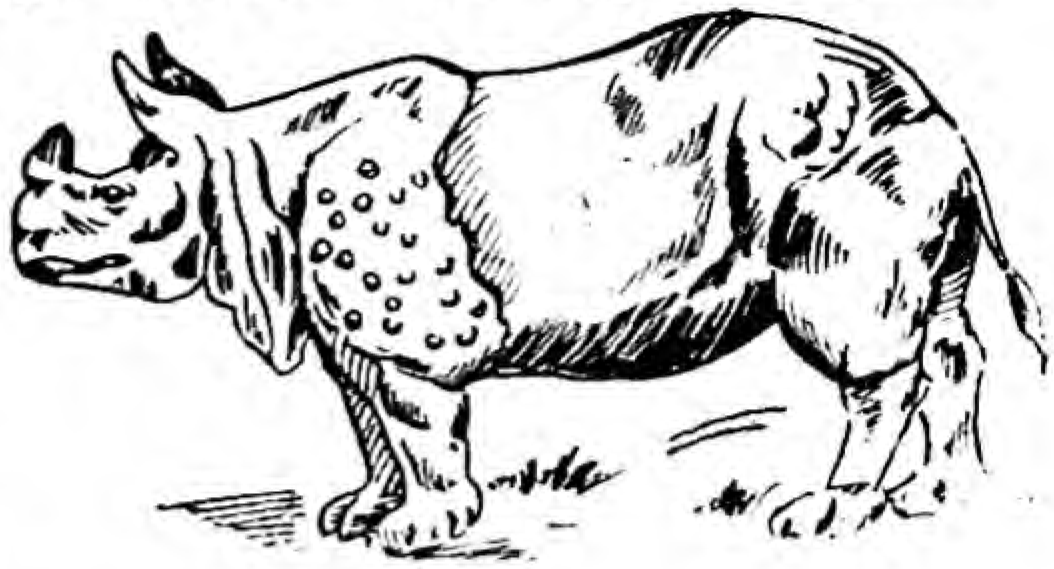


Fig. 36.61. Indian Rhinoceros (*Rinoceros unicornis*)

Horses, Asses, Zebras. The horses, asses and zebras (*Equus*) have a

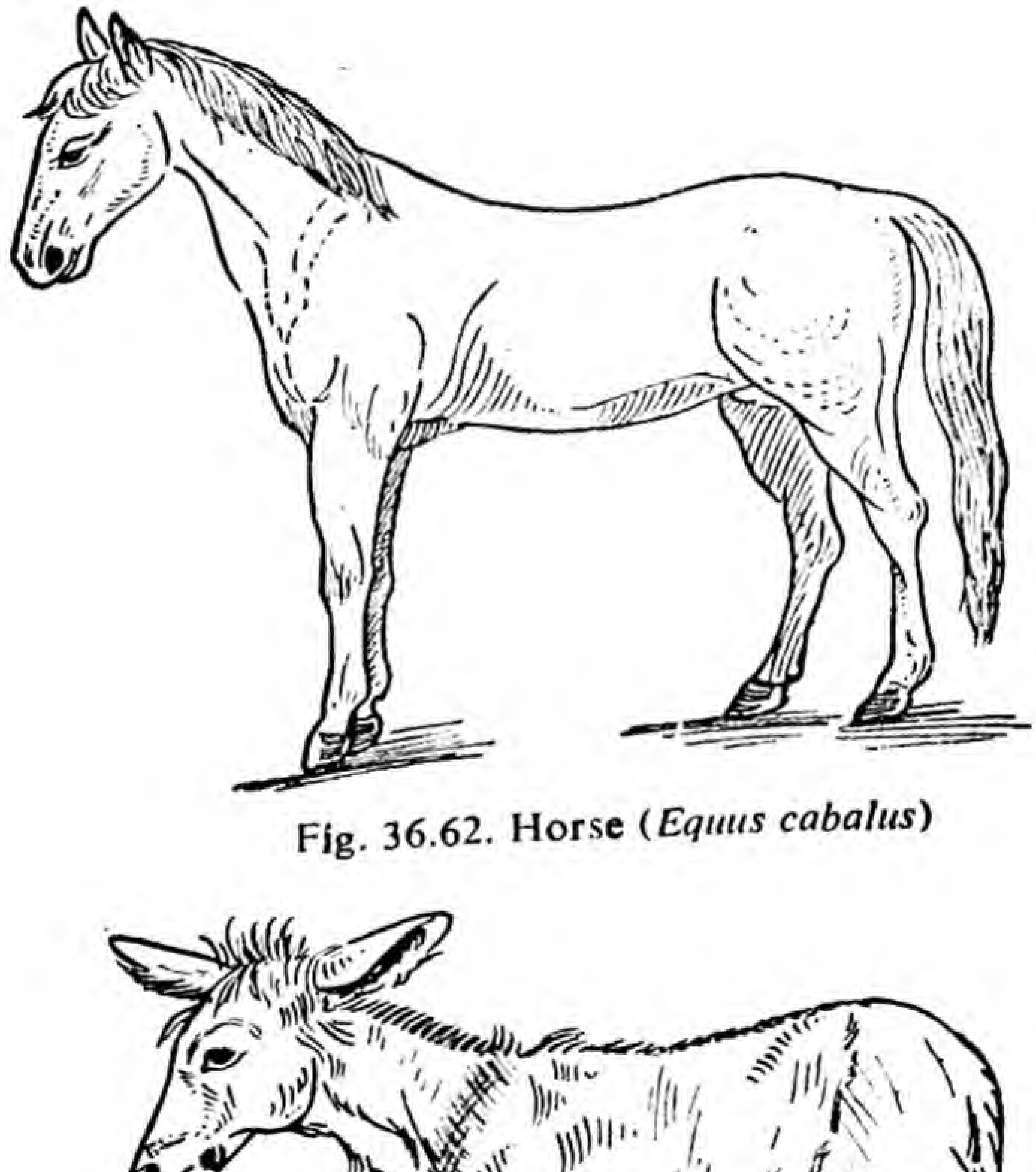


Fig. 36.62. Horse (*Equus cabalus*)

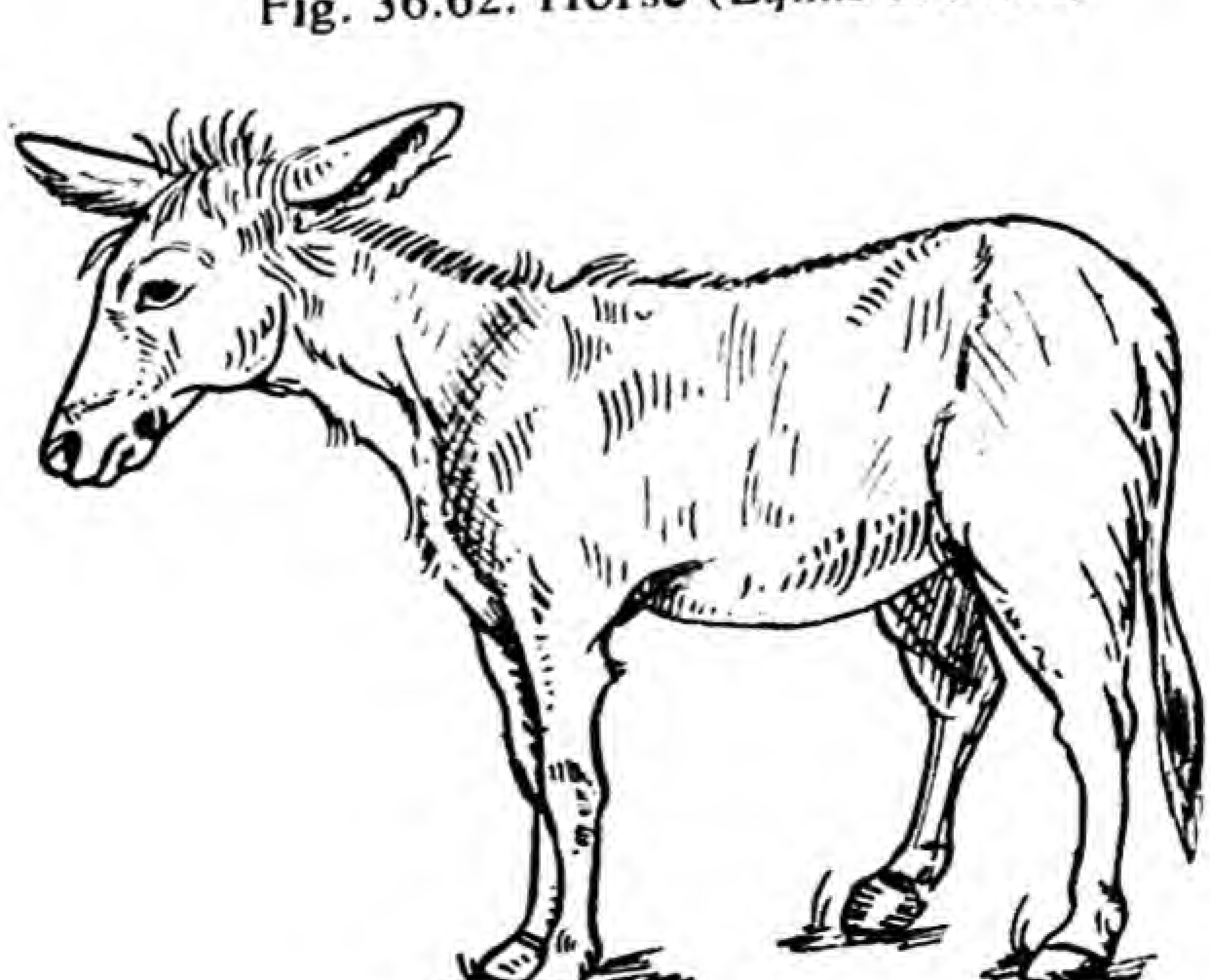


Fig. 36.63. Ass (*Equus asinus*)

single functional digit (the third) which is enclosed in a solid hoof. The second and fourth digits are reduced to splint bones while the first and fifth digits have altogether disappeared.

TABLE 27

Horse	Ass
(*Equus Cabalus*)	(*Equus asinus*)
1. Have a larger body, smaller head, shorter ears and broader hoofs.	1. Have smaller body, larger head, longer ears and narrower hoofs.
2. Mane long and pendant.	2. Mane short and erect.
3. Tail is completely covered with hair.	3. Tail bears hair only on the lower part.
4. Have bare callosities on all the four limbs.	4. Have bare callosities on the fore-limbs only.
5. Have no streaks or stripes.	5. Have a dark streak on the back and sometimes acros the shoulders also.
6. Do not occur in wild state.	6. Occur in wild state also.

Zebra (Fig 36.64). The zebra resembles the ass in all respects except that its body is fully striped.

Order (*x*) **Artiodactyla**. It includes the cattle, sheep, goats, deer, antelopes, camels, giraffes, pigs, hippopotami, etc. All these are terrestrial and herbivorous mammals. They have long limbs adapted for fast-running. Each limb has only two functional digits, the third and the

Fig. 36.64. Zebra (*Equus*)

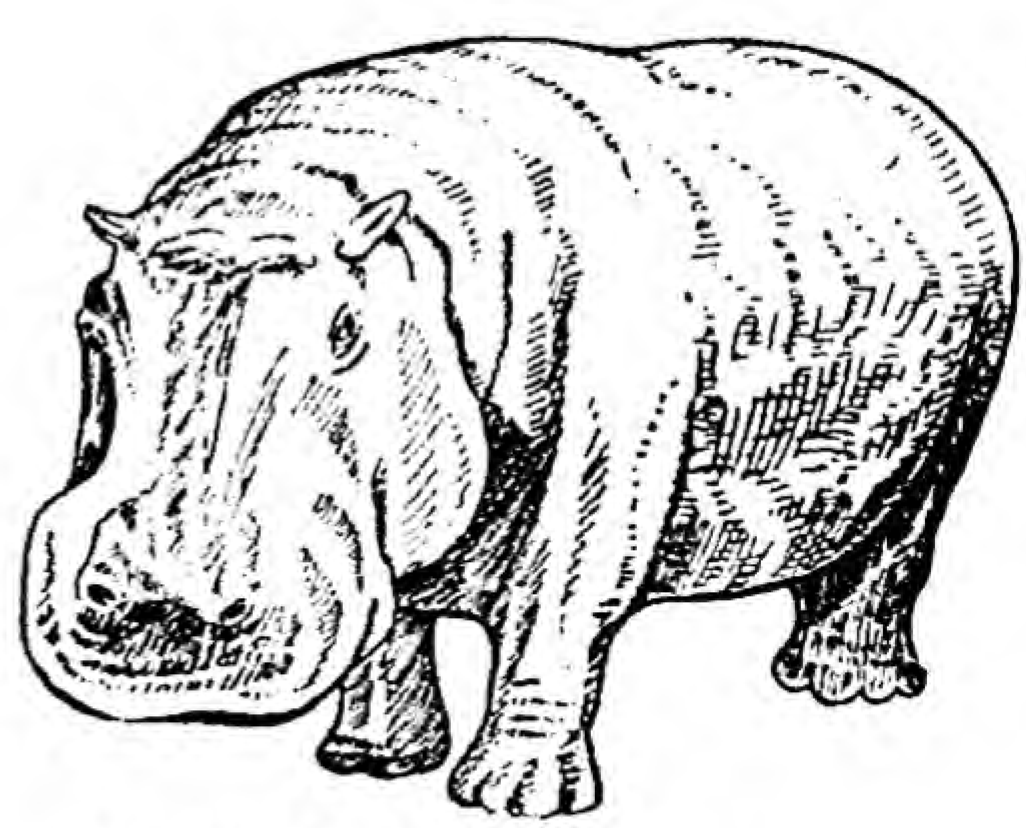


Fig. 36.65. Hippopotamus (*Hippopotamus*)

fourth, both equally developed. The main axis of the limb, that divides it into two halves, passes between the two functional digits. Each digit is enclosed in a cornified hoof. The mode of progression is unguligrade. Many forms possess horns or antlers on the head.

This order has two groups : non-ruminants and ruminants.

(*i*) **Non ruminants**. The non-ruminants have a relatively simple stomach and do not chew the cud. The examples are hippopotamus and pig.

Hippopotamus (Fig. 36.65). The hippopotamus (*Hippopotamus*) inhabits most of the rivers and lakes of Africa. Next to elephant, it is the bulkiest of all the terrestrial mammals It has a long, deep, barrel-shaped body covered with thick warty, almost naked skin. The head is enormous in size and has a transversely expanded bristly snout. The neck is extremely short but very powerful to support the huge head. The short tail is laterally compressed. The legs are very small, each bearing four partially webbed digits. The animal is nocturnal, herbivorous and gregarious.

(*ii*) **Ruminants.** The ruminants have a complicated stomach, comprising four chambers : **rumen, reticulum, psalterium and abomasum.** (Fig. 36.66). While feeding, they swallow their food rapidly and store it in a chamber called the **rumen**. From here, the food is regurgitated, a mouthful at a time, chewed thoroughly and swallowed again. This process is called **chewing the cud or rumination.** This group includes the cattle, sheep, goats, deer, camels and giraffes.

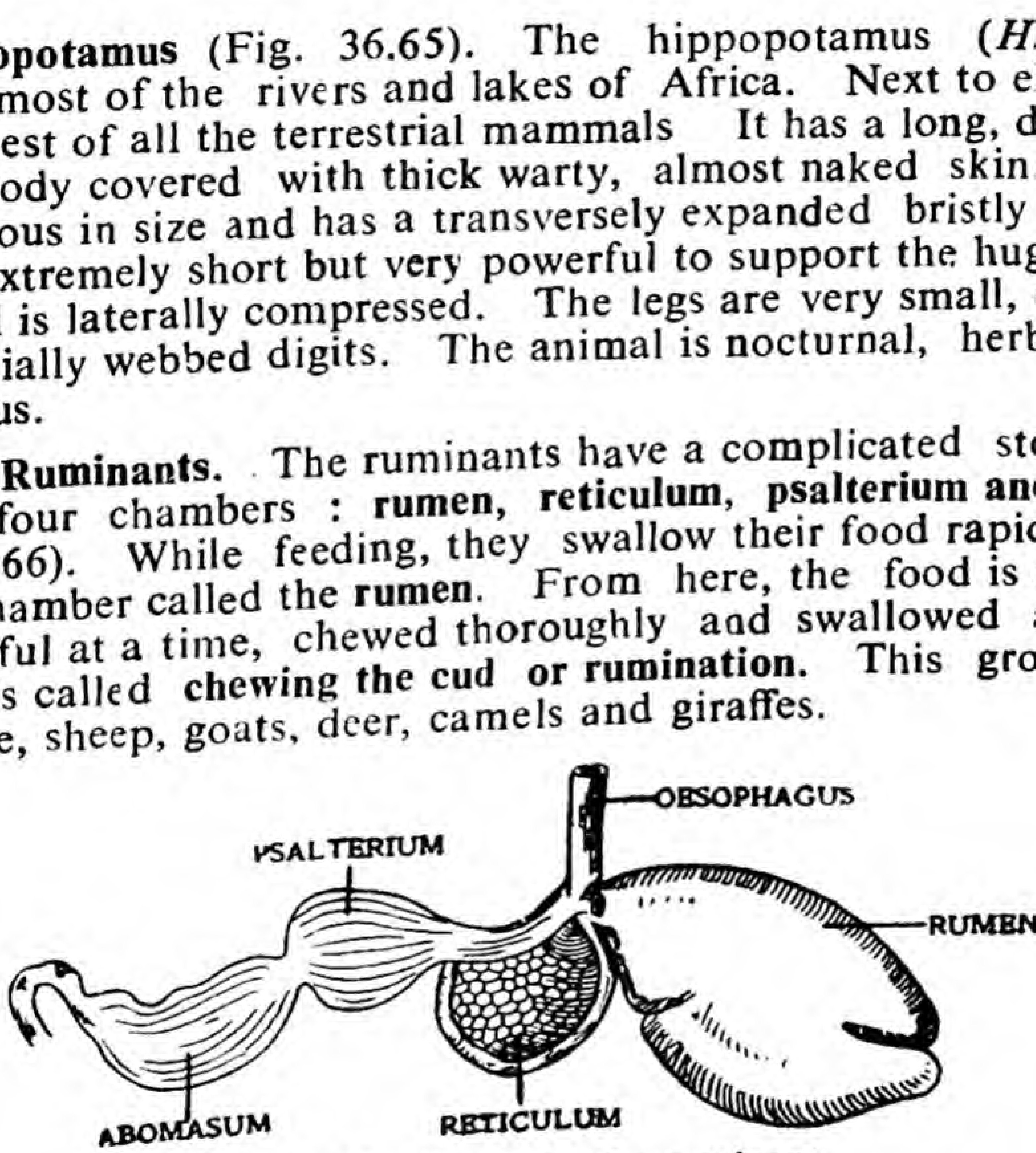


Fig. 36.66. Stomach of a ruminant

Cattle, Sheep, Goats (Fig. 36.67) The oxen (*Bos*), sheep (*Ovis*) and goats (*Capra*) have true horns, which consist of a bony core covered with a horny epidermal sheath. The horns are unbranched, grow continuously and are never shed. They usually occur in both the sexes, though larger in the males.

Deer (Fig. 36.68). The deer (*Cervus*) bears antlers. They are branched and consist only of bone without any covering of horn or skin. They are shed and grow anew every year. They occur only in the males except the reindeer in which both the sexes bear them.

Camel (Fig.36.69). The camel (*Camelus*) is without horns and antlers. The upper lip is divided like that of a rabbit. The feet form broad cushions which are undivided on the underside but split into

two toes in front. The stomach has only three chambers. The first two chambers have a number of pouches, each with a sphincter muscle. These pouches are called the water cells as they serve to store water.

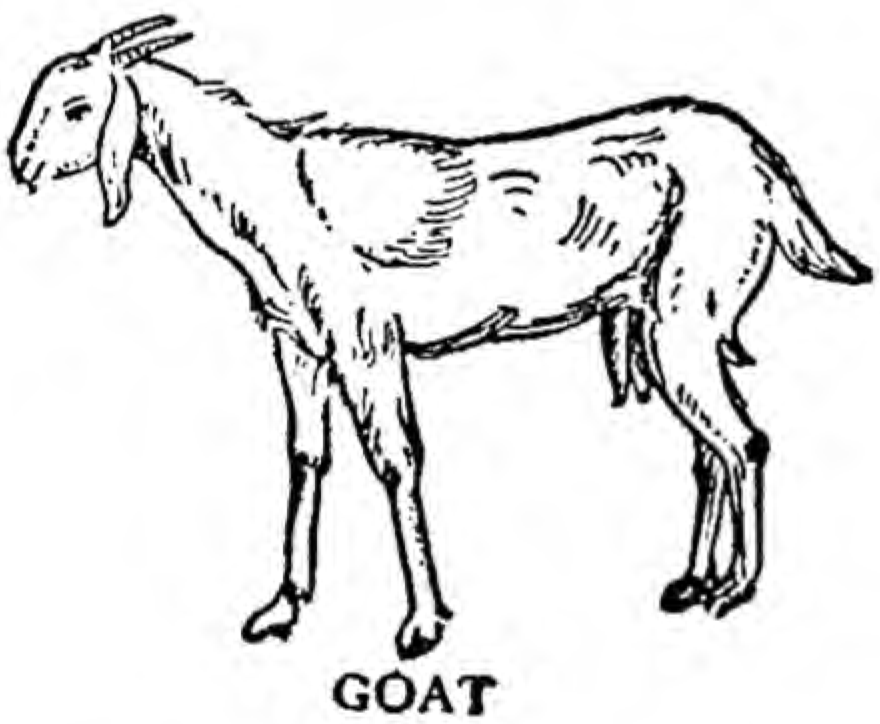


Fig. 36.67. Goat (*Capra*)

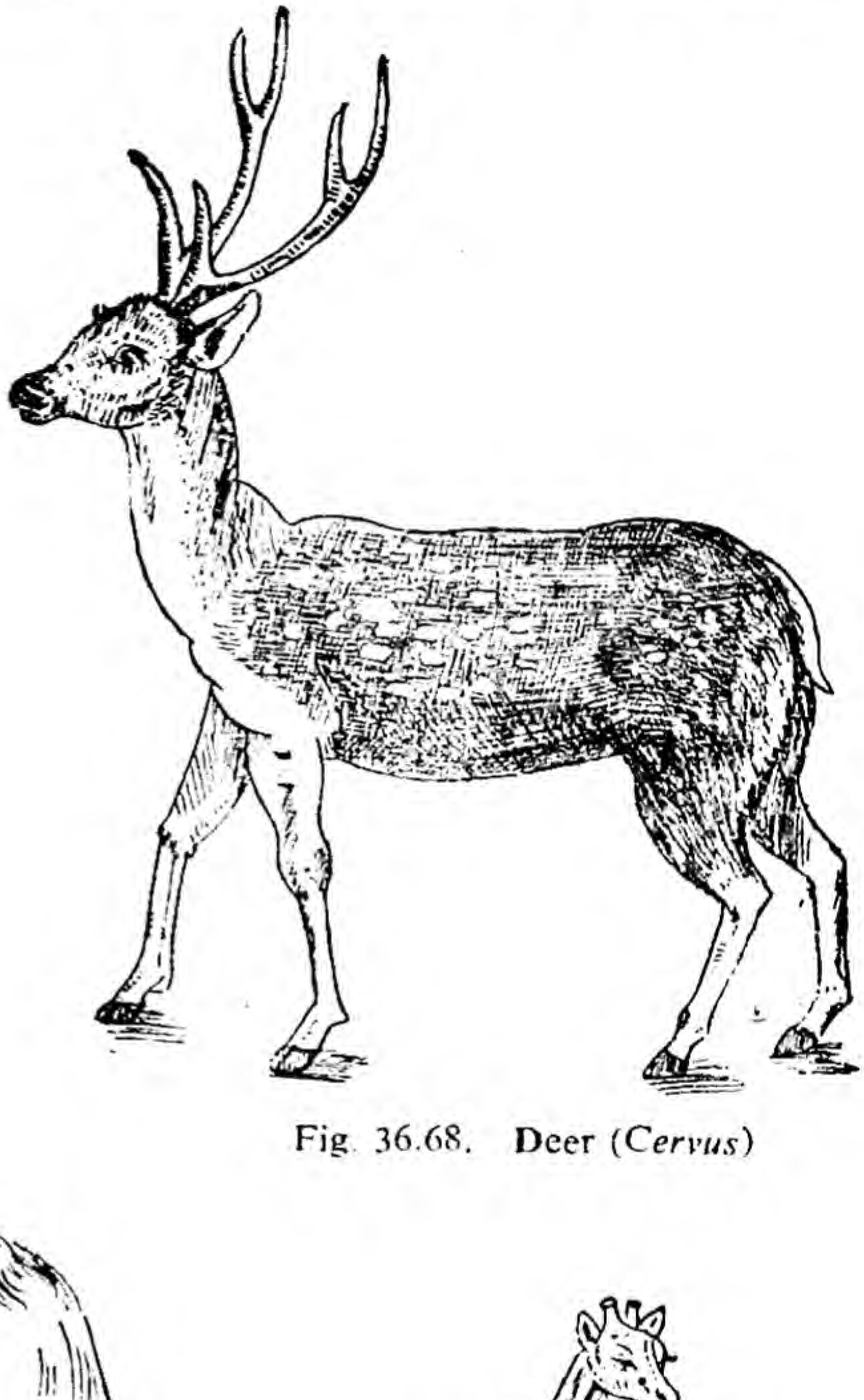


Fig. 36.68. Deer (*Cervus*)

Fig. 36.69. Arabian or one-humped camel (*Camelus dromedarius*)

Fig. 36 70. **Giraffe** (*Giraffa camelopardalis*)

There are two types of camels : the Arabian or one-humped camel and the Turkish or two-humped camel.

Giraffe (Fig. 36.70). The giraffe (*Giraffa camelopardalis*) inhabits the desert-like regions of Africa, south of the Sahara. It has a height of about 548—610 centimetres and enjoys the title of the tallest mammal. The head is delicate and bears a pair of bony horns covered with skin. There is a median dome-like elevation between the eyes. The neck is very long and has short erect mane. The trunk is comparatively short. The tail is considerably long and ends in a tuft of hair. The limbs are extremely long, particularly, the anterior ones

The giraffe lives in herds. It feeds exclusively on the leaves which are plucked one by one with the long flexible tongue. It defends itself by kicking out with the legs.

Economic Importance of Vertebrates.

Fishes. Fishes are useful to man in the following ways :—

1. *They provide food.* Many fishes like cod, salmon, herring, mackerel, carps, cat-fishes and mullets are eaten all over the world.

2. *They provide products of commercial value.*

(*a*) *Fish Oil.* Liver of certain fishes, *e.g.* cods and sharks, yields large quantities of oil. This oil in crude form is used in paints and insecticide sprays. In the refined form, it is taken as a source of vitamins A and D.

(*b*) *Fish Meal.* Scraps from canneries and entire fishes of some species are dried and ground into a meal. This meal is used for feeding poultry and as a fertilizer.

(*c*) *Leather.* The skin of certain sharks is used as leather for the manufacture of shoes and hand bags.

(*d*) *Shagreen.* Shark skin tanned along with its covering of scales is called shagreen which is used as abrasive for polishing wood. It is also used for binding books and as a covering for jewel boxes.

3. *They provide recreation.*

(*a*) *Sport.* Fishes like trout and perch are hunted for sport.

(*b*) *Hobby.* Some people keep brightly-coloured fishes, *e.g.* the gold-fish, in small aquaria in the houses for decoration and fun.

4. *They help in the control of malaria.* A few fishes, like *Gambusia* (top minnow), eat up mosquito larvae and are introduced in ponds and tanks for the control of malaria through the destruction of mosquitoes.

5. *They provide livelihood.* Many persons are engaged in the fish trade and also in the industries which prepare fish products.

6. *They are used in scientific studies.* Certain fishes are dissected in the laboratories for acquiring knowledge of life.

Certain fishes are harmful also. The carnivorous forms like sharks feed on other fishes, lobsters, etc. which form human food. Larger

sharks (*Charcarius*) and sting rays attack man. Many fishes damage nets of fishermen.

Amphibia. The amphibians help mankind in the following ways :—

1. *They serve as food.* The amphibian flesh tastes somewhat like veal or chicken and is regarded as a great delicacy in many countries. The forms usually eaten are bullfrogs, legs of smaller frogs and axolotles.

2. *They destroy harmful insects.* Frogs and toads eat large quantities of insects and, thus, keep the population of insect pests under control.

3. *They are employed in scientific study.* The frogs are used for dissections by the students of elementary courses in zoology, physiology and pharmacology.

4. *They have medicinal value.* Toads have long been used in medicine by Chinese. Their skin contains digitalis-like secretions which probably have some therapeutic value.

Besides this, frogs are used as fish bait. They are fed upon by some food fishes and birds. They are kept as pets for recreation. There is a jumping frog contest for pet bullfrog in U.S.A.

Reptilia. The reptilians serve the human interest in the following ways :—

1. *They provide food.* Tortoises and turtles are in great demand as articles of food in many parts of the world. Some snakes and lizards are also edible.

2. *They destroy rodents and insects.* The snakes and lizards benefit man by eating up the harmful insects and rodents.

3. *They provide fancy leather.* Skin of crocodiles, alligators, large snakes and lizards is used as fancy leather for the manufacture of shoes, purses, etc.

4. *They give 'tortoise shell.'* The 'tortoise shell' of commerce is obtained from the carapace of the hawksbill turtle (*Eretmochelys imbricata*). It is used in the preparation of combs and ornaments.

5. *They are kept as pets.* Snakes and young turtles are kept as pets by some people. The snake-charmers earn their living by exhibiting their pet snakes to the public.

6. *They act as laboratory animals.* Certain lizards like *Uromastix*, *Varanus*, etc. are dissected and studied in the biology laboratories. Many persons are engaged in the trade of these animals and earn their livelihood.

7. *They provide poison for human use.* The poison of cobra is used to relieve intense pain in the cases of inoperable cancer of human tissues. Primitive people poisoned their arrows with snake venom to kill the prey and enemies.

The reptiles are harmful also. Poisonous snakes are responsible for a large number of deaths annually in the tropical countries. Many snakes destroy the eggs of useful birds. They also attack poultry at night.

Aves. The birds serve humanity in the following ways:—

1. *They destroy harmful insects.* A large number of birds exclusively feed on insects many of which are serious pests. House-sparrow can take 200—250 insects per day. Myna takes an equal number of injurious grasshoppers. White stork and rosy pastor cut locusts into pieces.

2. *They destroy injurious rodents.* Birds like owls, hawks, eagles, etc. render a very important service to man by destroying rats and mice which damage standing crops, devour stored grains and spread diseases.

3. *They eat up seeds of harmful weeds.* Certain birds check the growth of weeds by feeding on their seeds. This saves the farmers a good deal of money, time and labour.

4. *They act as natural scavengers.* Birds like vultures, kites, crows, etc. feed upon the carcases and refuse and, thus, clean the surface of the earth.

5. *They pollinate our flowers.* The match industry of India depends on the bird pollinators for the raw material. The birds pollinate flowers of silk-cotton tree whose wood is used in the match industry.

6. *They disperse the seeds and fruits of plants.* Bulbuls disperse the seeds of sandalwood trees in South India. Many birds disseminate the seeds of mulberry in the Panjab.

7. *They provide useful products* :

(*a*) *Feathers.* The feathers of egrets, golden eagles and peafowls have decorative value. Feathers of certain birds are used in stuffing pillows, making shuttle-cocks and preparing head combs.

(*b*) *Edible Nests.* The edible nest swiftlet (*Collocalia*) of West India and Burma prepares nests from saliva. The nests are eaten in China where they were exported in large numbers.

(*c*) *Guano.* The excreta of certain birds (Gannets, Cormorants and Pelicans) is used as a fertilizer under the name of Guano as it contains a large proportion of phosphoric acid and nitrogen. It is found in the islands of the South Pacific Ocean.

8. *They are employed in scientific study.* Pigeons are extensively dissected by the students of zoology everywhere.

9. *They furnish food* Fowls, ducks, partridges, quails, pigeons and many more are eagerly sought for as articles of food all over the world. The eggs of poultry are also extensively taken.

10. *They afford recreation.* Many people keep birds like pigeons, myna, parrots, quails, etc. and play with them at leisure.

Birds are harmful also. They pick up seeds as the farmer sows them; they eat up ripe grains from standing crops ; they injure all kinds of

fruits ; they devour certain useful insects and fishes; they pollinate the flowers of harmful plants ; they disperse the seeds of weeds ; they spread diseases among the domestic animals and they sometimes prove a nuisance in the house.

Mammalia. The mammals work for man in the following ways:—

1. *They serve as means of transport and beasts of burden.* Cattle, horses, asses, mules, camels and elephants are abundantly used for carrying men and goods from place to place. Dogs and reindeer are also used for this purpose in certian parts of the world. Cattle and horses are employed in agricultural operations also.

2. *They provide food.* Goats, sheep rabbits, hares, deer, calves, pigs, and many more are eaten all over the world. Cows, buffaloes and goats yield milk. Milk is also obtained from lamas, camels and reindeer.

3. *They give many products of commercial value, e.g.*

(*a*) *Leather.* The skin of cattle is made into leather for preparing shoes, bags, straps, and purses.

(*b*) *Fur.* Mammals like otters, minks, weasels, foxes, seals, rabbits, etc. are hunted for fur to be used in the preparation of garments, purses, gloves and the like.

(*c*) *Wool.* Sheep provide the most important animal fibre without which it is not possible for us to survive in winter. Goats, alpaca and camels also yield wool.

(*d*) *Musk.* The musk-deer of Central and Easten Asia gives musk from its glands.

(*e*) *Ivory* The tusks of elephants and walruses yield ivory.

(*f*) *Ambergris.* It is obtained from the intestine of sperm whales and is used in perfumery.

(*g*) *Oil and Fat.* An edible oil is obtained from the blubber of whales and seals. This oil is also used as fuel by Eskimos in the Arctic Region. Cooking fat is procured from the pigs.

(*h*) *Glue and Gelatin.* Bones, horns and hoofs of cattle yield glue and gelatin.

(*i*) *Fertilizer.* The bone-meal prepared by crushing the bones of cattle, sheep and horses forms an important fertilizer. Their dung is an excellent manure and also yields fuel gas.

(*j*) *Antlers.* The antlers of deer have decorative value.

(*k*) *Hair.* Hair of certain mammals are used for making brushes.

4. *They provide recreation, e. g.*

(*a*) *Game.* Deer, lions, foxes, bears, and hares are hunted for pleasure.

(*b*) *Pets*. Dogs, mongooses, rabbits and monkeys are kept as pets by some people who play with them at leisure. Dog has been associated with man as his pet and guard from times immemorial.

(*c*) *Zoo*. Larger and rarer mammals are exhibited in the zoological gardens and national parks for curiosity and amusement.

5. *They are used as laboratory animals*. Guinea pigs, monkeys, dogs and rats are extensively used for research in physiology, genetics and space-travel.

6. *They destroy harmful animals*. Cats destroy rats which are very dangerous to man. Many mammals eat up harmful insects, Mongoose kills snakes, lizards and rats.

Mammals work against the human interests in the following ways:—

1. *They destroy useful crops and trees*. Rabbits, hares, rats, deer and other herbivores destroy all sorts of crops and fruit-trees.

2. *They damage human possessions*. Rats and mice damage buildings, consume food-stuffs, impair furniture and books and destroy clothes, carpets, ete. Cats eat up foods in the kitchens.

3. *They spread diseases*. Rats spread plague. Pigs serve as intermediate hosts for tapeworms.

4. *They destroy useful animals*. Many carnivores feed on useful animals like domestic cattle, sheep, pigs, poultry, etc. Some forms are dangerous even to man.

Summary

Phylum **Chordata** (kor-day-ta) : With notochord, gill-slits and dorsal hollow central nervous system.

Sub-phylum (*a*) **Hemichordata** (he-mee-kor-day-ta) : Worm-like body with proboscis, collar, and trunk, *e.g.* acorn worm.

Sub-phylum (*b*) **Urochordata** (You-ro-kor-day-ta) : Sac-like body, notochord confined to larval tail, *e.g.* sea-squirt.

Sub-phylum (*c*) **Cephalochordata** (se-fa-lo-kor-day-ta) : Fish-like body, permanent notochord reaching head, *e.g.* lancelet.

Sub-phylum (*d*) **Vertebrata** (Var-ta-bray-ta) : With vertebral column.

Super-class **Agnatha** (ag-nay-tha) : No jaws.

Class 1. **Cyclostomata** (sy-klo-sto-may-ta) : Round-mouthed jawless fishes, *e.g.* lamprey.

Super-class **Gnathostomata** (Na-tho-sto-may-ta) : With jaws.

Class 1. **Chondrichthyes** (kno-drik-thi-eez) or **Elasmobranchii** (ee-laz-mo-branch-ee-eye) : Cartilaginous skeleton, *e.g.* shark, ray.

Class 2. **Osteichthyes** (os-te-ik-thi-eez) : Bony skeleton.

Sub-Class **Actinopterygii** (Ak-ti-no-te-rig-ee-eye) : air-bladder acts as hydrostatic organ. *e.g.* **cat-fish, flying fish, climbing perch.**

Sub-Class **Choanichthyes** (Ko-ai-nik-thi-eez) ; air-bladder acts as a lung, *e.g.* African mud-fish.

Class 1. **Amphibia** (am-fib-ee-a) : Gills present at some stage, no exoskeleton, digits without claws.

Order *i.* **Urodela** (you-ro-dee-la) : Tailed forms, *e.g.* salamander.

Order *ii.* **Anura** (ay-nyorra) : Tailess form, *e.g.* frog, toad.

Order *iii.* **Apoda** (ap-o-da) : No tail and limbs, *e. g. Uraetyphlus.*

Class 2. **Reptilia** (rep-til-ee-a) : Breathe with lung, have scales, digits with claws.

Order *i.* **Chelonia** (ke-lo-nia) : Body short and broad, enclosed in bony shell, *e.g.* tortoise, turtle.

Order *ii.* **Squamata** (squa-may-ta) Scaly exoskeleton, moulted at intervals.

Sub-order (a) **Lacertilia** (la-ser-ti-lee-a) : With limbs, *e.g.* wall-lizard, *Chamaeleon*, flying dragon.

Sub-order (b) **Ophidia** (of-ee-dee-a) : No limbs, *e.g.* snakes.

order *iii.* **Crocodilia** (krok-dil-ee-a) : Exoskeleton of scales and bony plates, body lizard-like, *e.g.* crocodile, gaviale.

Class 3. Aves (ay-veez) : Feathered, bipedal, warm-blooded vertebrates.

Sub-class (a) **Archaeornithes** (ar-kee-or-ni-theez) : Extinct birds resembling reptiles, *e.g. Archaeopteryx.*

Sub-class (b) **Neornithes** (ne-or-nitheez). Modern birds.

Super-order I. **Palaeognathae** or **Ratitae** (ray-ti-tee) : Flightless birds, wings and keel reduced, *e.g.* ostrich.

Super order 2. **Impennae** : Penguins, wings form flippers.

Super-order 3. **Neognathae** or **Carinatae** (ka-ree-na-tee) : Flying birds, wings and keel well-developed, *e.g.* pigeon, owl, duck, fowl.

Class 4. **Mammalia** (mam-ay-lee-a) : Hairy, warm blooded, viviparous vertebrates with milk glands.

Sub-class (*a*) **Prototheria** (pro-to-thee-ri-a) or **Monotremata** (mon-o-tree-may-ta) :Egg laying mammals, *e,g.* duck-bill, spiny ant-eater.

Sub-class (*b*) **Theria** (thee-ri-a) : Young producing mammals.

Infra-class (*i*) **Metatheria** (meta-thee-ri-a) or **Marsupialia** (mar-soo-pee-ay-lee-a) : Pouched mammals, *e.g.* kangaroo.

Infra-class (*ii*) **Eutheria** (you three-ri-a) or **Placentalia** (play-sen-tay-lee-a) : Placental mammals.

Order *i.* **Insectivora** (in-sek-ti-vor-a) : Insect-eating mammal, *e.g.* hedgehog.

Order *ii.* **Primates** (pry-may-teez) : Fore-limbs adapted for grasping, walk erect or semi erect. *e.g.*lemur, loris, monkey, ape ,man.

Order *iii*. **Chrioptera** (ky-rop-ter-a) : Flying mammals. *e.g.* bats.

Order *iv*. **Rodentia** (ro-den-shia) : Incisors adapted for gnawing, *e.g.* rat, squirrel.

Order *v*. **Lagomorpha** (lag-o-mor-fa) : Hind-limbs adapted for jumping, *e g*. rabbit, hare.

Order *vi*. **Cetacea** (see-tay-sha) : Marine, fish-like mammals, fore-limbs fin-like. hind limbs absent, *e.g.* whale, dolphin.

Order *vii* **Carnivora** (kar-ni-vo-ra) ; Canine teeth and claws well-developed.

Sub-order (*a*) **Fissipedia** (fis-ee-pee-dee-a) : Terrestrial carnivores, *e.g*, cat, lion, tiger, bear.

Sub-order (*b*) **Pinnipedia** (pin-ee-pee-dee-a) : Aquatic carnnivores. *e. g.* seal.

Order *viii* **Proboscidea** (pro-bos-i-dee-a). Upper lip and nose elongated to form trunk, inicisors form long tusks, *e.g.* elephant.

Order *ix*. **Perissodactyla** (Peri-so-dak-ti-la) : Even-hoofed, *e.g.* horse zebra, ass, *Rhinoceros*.

Order *x*. **Artiodactyla** (ar-tee-o-dak-ti-la) Even-hoofed, *e.g.* cattle, giraffe, camel, pig, hippopotamus, goat, sheep.

TEST QUESTIONS

1. Discuss the distinguishing characters of the phylum Chordata.
2. Name the various sub-phyla of the Phylum Chordata giving one example of each. What are the general features of the vertebrates ?
3. Give the taxonomic position of the following animals and write a brief note on each :—
   Shark, Electric Ray, Climbing Perch, Sea-horse, Flying Fish, Flat Fish, Lung Fish.
4. Discuss the economic importance of fishes.
5. Give the differences between the Chondrichthyes and Osteichthyes.
6. Write a brief note on the habitat and habits of the following animals. Also refer them to their respective placesion the anmial kingdom—*Draco*, Chamaeleon, Crocodile, Cobra, Ostrich, Duck. Owl, Duck-bill, Kangaroo, Bat, Hedge-hog, Giraffe, whale.
7. How do the following animals differ from each other :—
   Frog and Toad, Horse and Ass ; Tortoise and Turtle : Salamander and wall-lizard : Lemur, Monkey and Ape, Cobra, Krait and Viper, Lion, Tiger and Leopards, Rabbit and Hare.
8. Discuss the importance of birds or mammels to mankind.
9. Name and describe the following :—
   (*a*) Three types, of foot posture in mammals.
   (*b*) An animal which can change colours.
   (c) Two aquatic mammal.
   (*d*) A flightless bird.
   (*e*) Two non-poisonous snakes.
   (f) Two egg laying mammals.
10. What is the technical name of man ? How do ape and man differ ?
11. Justify the undermentioned statement :
    Bat and whale are mammals.

CHAPTER 37

Variations

Definition

Variation is the only invariable law of nature, Everything in the universe gradually changes. The planets and stars alter their relative positions, the continents and oceans modify their boundaries, the climate varies, and the social structure changes. The principle of change equally affects the animals and plants. In fact, animals and plants must change in order to adopt themselves to the changing environment. Otherwise, they cannot survive long. This is why no two individuals of a species are ever exactly alike. Even the offspring of the same parents have individual peculiarities along with the strong resemblance with each other and the parents. 'Like begets like', thus, has a limited application. The differences shown by the individuals of the same species and offspring of the same parents are known as **variation.** The principle of variations is not only universal but also highly extensive. All organisms always show variations in every character and in all directions. Absolute uniformity is conspicuous by its absence in the organic world.

Classification

Variations can be classified in two ways : according to the nature of the cells they affect and according to the their magnitude.

1. With regard to the nature of the cells affected, the variations are of two types, namely, somatic and germinal.

Somatic Variations. The somatic variations are also known as the **somatogenic variations.**

Definition. The somatic variations, as their name indicates, affect the somatic cells of the organism. They are neither inherited from the parents nor transmited to the next generation. They are acquired by the individual during its own life and are lost with its death. They are, therefore, also called the **acquired variations**. They are non-inheritable because the sole connection between the parents and the offspring is through the germ cells.

Causes. The somatic variations are produced by three factors : environment, use and disuse of organs and conscious efforts.

(*i*) **Environment.** Environment affects the organism through changes in light, medium, food, air. etc. The following experiments show the role of environmental factors in the production of variations.

(a) *Cunningham's Experiment*. Take a normal flat fish (*Solea*) which is pigmented above and white below. Keep it in a glass aquarium. Throw light on the lower white surface and prevent all light falling on the upper surface. After some time it will be found that the upper surface of the fish turns white and the lower develops pigmentation. It thus, shows that the fish develops pigmentation in response to light only.

(b) *Stockard's Experiment*. Take a few eggs of the fish *Fundulus* in a dish containing sea-water. Add some magnesium chloride to change the nature of the medium. It will be found that the eggs hatch into peculiar fish having a single median eye instead of two lateral eyes which they possess when hatched in the normal medium.

(c) Select two similar young ones of rabbit and subject them to different conditions of food and air. The one who gets nourishing diet and plenty af fresh air will become stronger than the one kept ill-fed.

(*ii*) **Use and Disuse of Organs**. The use and disuse of organs also produce variations. The continuous use of an organ results in its better development while by the constant disuse the organs become reduced. A player who uses his muscles in daily exercise acquires a stronger and more muscular physique than the one who does not take exercise. The same is true of the animals. A lion kept in the zoo is weaker than that living in the natural environments. This is so because the former does not use its body to capture the food while the latter struggles for it.

(*iii*) **Conscious Efforts**. Variations are also produced by conscious efforts of human beings. The example of such variations are many. To mention only a few, we have mutilations, *i.e.* cutting of tail and limbs in animals ; boring of pinna in the Indian women ; achieving slender waists by using tight garments and belts in European woman ; restricting the growth of feet by wearing tight shoes in the Chinese receiving education ; learning an art ; forming habits and so on.

Lamarck (1744—1822) held that the variations acquired by the effects of environment, use and disuse of organs, and conscious efforts are inheritable and formed them the keystone of his theory of evolution. But later on it was shown by Weismann (1834—1914) that the acquired characters are non-inheritable. In certain cases, however, the acquired character- are actually inheritable due to unknown reason.

2. **Germinal Variations**. The germinal variations are also known as the **blastogenic variations**.

Definition. The germinl variations, as suggested by their name, affect the germ cells of the organism and are, consequently, inheritable. They are received by the individual from the parents and are transmitted to the next generation.

Causes. The blastogenic variations are due to new combinations of the a'ready present characters (or chromosomes). Sexual reproduction which involves the mixing up of the **germ cells** of two parents, provides

almost infinite chance of new combinations. The new combinations arise at two steps: firstly, during the formation of gametes at the reduction division and then at the time of fertilisation of the gametes.*

1. **Continuous Variations.**

Definition. The continuous variations may be defined as small, imperceptible but very frequent departures on both sides of the normal type with which they are connected by intermediate stages. They are known as the continuous variations because they merge into each other by small gradations. They are also called fluctuating variations or fluctuations as they fluctuate on either side of the normal type. They are found in all the animals and plants and affect all of their organs.

Types. Continuous variations are of 2 types : substantive and meristic.

(*a*) **Substantive Variations**. These affect shape, size and colour of the organism or of its parts, *e.g.* height, skin colour, and shape of the nose in man.

(*b*) **Meristic Variations.** These affect the number of parts, *e.g.* six sepals or petals in a pentamerous flowers.

Darwin held that the continuous variations are inheritable and formed them the basis of his theory of evolution.

2. **Discontinuous Variations.**

Definition. The discontinuous variations may be defined as large, conspicuous and sudden but rare departures from the normal type with which they are not connected by intergradations. These variations are also called the mutations, sports or saltations. They are inheritable.

Types. These variations also are of 2 types : substantive and meristic.

(*a*) **Substantive Variations.** These affect the shape, size and colour of the organism or of its parts. *e.g.* (*i*) the Ancon sheep which is a short-legged variety developed from the normal sheep in 1891 in a single generation, (*ii*) the hornless or polled Hereford cattle which developed from the normal cattle in 1889 in a single generation, and (*iii*) the hairless cats, dogs and mice which have arisen from the normal parents in a single generation. All these mutants breed true.

(*b*) **Meristic Variations**. These affect the number of parts, *e.g.* supernumerary digits in man.

Causes. The causes of discontinuous variations are blastogenic. They arise from unequal distribution of characters during gamete formation. In rare cases, after synapsis, the chromosomes do not separate. The diploid gamete fertilized by haploid gamete will result

*The student is advised to refresh his knowledge of cell division.

into a triploid zygote. The latter develops into an organism with characters entirely different from those of either parent, but inheritable. Polyploids have recently been produced artificially by treatment with colchicine. Being blastogenic, the discontinuous variations are inheritable. The reason of their origin is obscure.

Significance.

The variations have a manifold significance—

1. They form raw material for evolution. Without variations, older species will not change into new ones and there will be no evolution.

2. Variations enable the animals to adapt themselves to changing environment.

3. Variations help man in improving the races of useful animals and plants.

4. Without variations, there would be no science of heredity at all. All the individuals of a race would be exactly identical in all respects and heredity will offer no problem.

TEST QUESTIONS

1. What are variations ? Name and describe the types of variations with regard to the cells they affect.

2. Write all you know about the continuous and discontinuous variations.

3. Discuss the significance of variations.

CHAPTER 38

Heredity

Definition of Heredity

The offspring generally resemble their parents. This resemblance is, however, never complete. The young ones almost always have a few individual peculiarities in which they differ from their parents. The similarities, and in many cases differences also, are received by the offspring from the parents. This transmission of characters, resemblances as well as variations, from one generation to another is called **heredity** or **inheritance**. The branch of zoology which pertains to the study of inheritance of characters from generation to generation is, termed **genetics**.

Physical Basis of Heredity

In lower organisms, where the offspring are formed simply by division of the parent body, the transmission of characters is an easy affair. The young receives a part of parent's body and is therefore, after it. In higher organisms, where the body is composed of a large number of units or **cells**, the only connection between the parents and the offspring is furnished by the gametes, the egg and the sperm. It is, therefore, certain that the characters of the parents reach the young ones through the gametes. In other words, the gametes form the physical basis or carrier of heredity. This fact was brought to light by August Weismann (1884–1914) in his theory entitled "the **continuity of germplasm.**" This theory states that—

(*a*) the body of an organism consists of two very unequal components : the **germplasm** which includes the germ cells or cells of the gonads and the **somatoplasm** which comprises all other cells of the body.

(*b*) the germplasm bears hereditary characters and is passed on from generation to generation in the form of gametes, whereas the somatoplasm plays no role in heredity and perishes when the organism dies.

There is no doubt that the gametes carry characters from the parents to the offspring but they do not contain in them the characters as such. They contain 'something' which represents a character and is responsible for its appearance in the offspring. This 'something' is termed the **gene** in modern terminology. A gene may be defined as the unit of inheritance which is carried from the parent by a gamete and controls the development of a character in the young one in co-operation with

other genes and environment. The genes are located on the chromosomes in a linear order and the chromosomes in turn lie in the nucleus. We can now say that the characters travel from the parents to the offspring in the form of genes situated on the chromosomes present in the nuclei of the gametes.

Mendel's Experiments.

Gregor Johann Mendel was born of a peasant family in 1822. He became a monk and eventually an abbot in the Augustinian monastery at Brunn, Austria (now Brno in Czechoslovakia). He laid foundations of modern genetics. He conducted breeding experiments on the pea plant (*Pisum stivum*) in the garden of his monastery. He published his results in 1866 in the journal of the local Natural History Society. Unfortunately his results attracted little attention. He died in 1884. In 1920, however, his results were independently rediscovered by three biologists, namely, De Vries of Netherland, Correns of Germany and Tshermak of Austria. These scientists deserve all the credit for naming them after Mendel and for bringing them to the notice of the biologists.

Mendel noted in the garden pea seven characters which always appeared in contrasting pairs. The characters included :–

1. Size of the stem ... Tall or dwarf.
2. Position of the flower ... Axillary or terminal.
3. Colour of unripe pod ... Green or yellow.
4. Form of ripe pod ... Smooth or wrinkled.
5. Colour of seed coat... While or grey.
6. Colour of cotyledons ... Yellow or green.
7. Form of the seed ... Round or wrkinled.

Mendel considered one pair of characters at a time. He crosspollinated two pea plants, one tall (180—210 cm.) and the other dwarf (22—44 cm). He called them **parental generation,** expressed now-a-days by the symbol P. He collected the seeds produced by this cross and grew plants from them. All these plants were found to be tall. He described them as the **first filial generation,** indicated by the symbol F_1. The F_1 plants were subjected to self-pollination (called **selfing**) and the seeds produced were again collected and plants grown from them. These plants were designated as the **second filial generation**, indicated by the symbol F_2. The F_2 plants were found to contain both tall and dwarf individuals. They were in the ratio of three tall to one dwarf. This cross can be briefly expressed in the following graphic form—

```
P          Tall × Dwarf
                |
F1             Tall
             (selfed)
                |
         ---------------
         |             |
F2     3 Tall       1 Dwarf
```

Mendel further found that all the plants of F_2 generation did not behave in the same way on selfing. The dwarf plants bred true to dwarfness, *i.e.* they yielded draft plants on self-pollination. Of the tall plants, one was pure for tallness while others behaved like the plants of F_1 generation, giving rise to tall and dwarf plants in the ratio of 3 : 1. Mendel also noted that none of the plants in F_1 generation was intermediate in size between the two parents.

The results of these experiments led Mendel to infer that the gametes brought from the parents something which made the particular character appear in the next generation. This "something' was called by him a **germinal unit** or **factor**. He further deduced that the factors did not change even when the character was not expressed in the individual and that they could reappear in the later generation, *e g*. the factor for dwarfness did not appear in F_1 generation but appeared in F_2 plants.

Mendel published his conclusions in the form of two laws termed the **Mendel's law of Heredity**. These laws are : (*i*) the **law of segregation** and (*i*) the law of **independent assortment**. The study of these laws of heredity is called **Mendelism**.

Before studying the law of Mendel, it is advisable to learn the terms used in modern genetics and the mechanism of heredity as revealed by the modern researches in cytology.

Terms used in Modern Genetics

Allelomorphs. The germinal unit of factor of Mendel's terminology is known as the **gene** in modern gentics. There are two genes for every character, one for each of its two contrasting expressions. Thus, the character of size has two genes, one for tallness and the other for dwarfness. Similarly the character of skin colour is represented by two genes, one standing for blackness and the second for whiteness. A pair of genes representing the two alternatives of the same character are called the **allelomorphs** or simple **alleles**. Each member of the pair is said to be allelomorphic or allelic to the other.

Homologous Chromosomes. The allelomorphs lie on two separate chromosomes. These two chromosomes have the same size and shape. The chromosomes which are similar in all respects are termed the **homologous chromosomes**.

Dominant and Recessive Genes. Of the allelomorphic pair of genes, usually one gene expresses itself in the individual while the other remains unexpressed The gene which is capable of manifesting itself in the presence of its contrasting gene is known as the **dominant gene**. On the other hand, the gene which fails to express itself in the presence of its contrasting gene is called the **recessive gene**.

Pure and Hybrid Individuals. In an individual the two genes of a character may be similar in which case both of them stand for the same alternative of the character or dissimilar in which case they represent both the alternatives of the character. An individual is said to be **pure** or **homozygous** for a character when the two genes responsible for that character are alike and an individual is described as **hybrid** or **hetero-**

zygous for a character when the two genes controlling that character are dissimilar.

Mechanism of Heredity

A knowledge of cell division (mitosis and meiosis), gamete formation and fertilization is very essential for understanding the mechanism of heredity. It is suggested that the students should refresh their knowledge of these phenomena.

During mitosis, the chromosomes, along with their genes, duplicate themselves, producing two identical sets, of which one goes to each daughter cell. With the result, the two daughter cells have chromosome and genes exactly identical with those of the mother cell. During the formation of gametes, there occurs meiosis which produces quite a different state of affairs. In this type of cell division, the homologous chromosomes come together in pairs (synapsis). Soon, however, the two chromosomes of each synaptic pair separate so that one chromosome of each homologous pair goes to each daughter cell. This is the segregation of chromosomes and genes. Since the mature gamete possesses only one member of every homologous pair of chromosomes, its total number of chromosomes is half of that found in the primordial germ cells or the somatic cells. The chromosomes found in the mature gametes form the **haploid number** while those found in other cells constitute the **diploid number**.

In the segregation of the homologous chromosomes during reduction division, which chromosome of each pair is to go into which daughter cell is purely determined by a **law of chance.** This produces a number of combinations of chromosomes or characters. For example, a primordial germ cell with four pairs of chromosomes will show sixteen possible combinations of chromosomes at the reduction division and will produce the same number of gametes. The law of chance combination of chromosomes again operates at the time of fertilization so that the types of zygotes formed are more than the types of fusing gametes. **The whole secret of heredity, therefore, lies in the behaviour of the chromosomes during gamete formation and the manner of their subsequent fusion to produce the zygotes.**

Mendel's Laws of Heredity

Let us now consider the laws of heredity formulated by Mendel.

1. The Law of Segregation of Genes

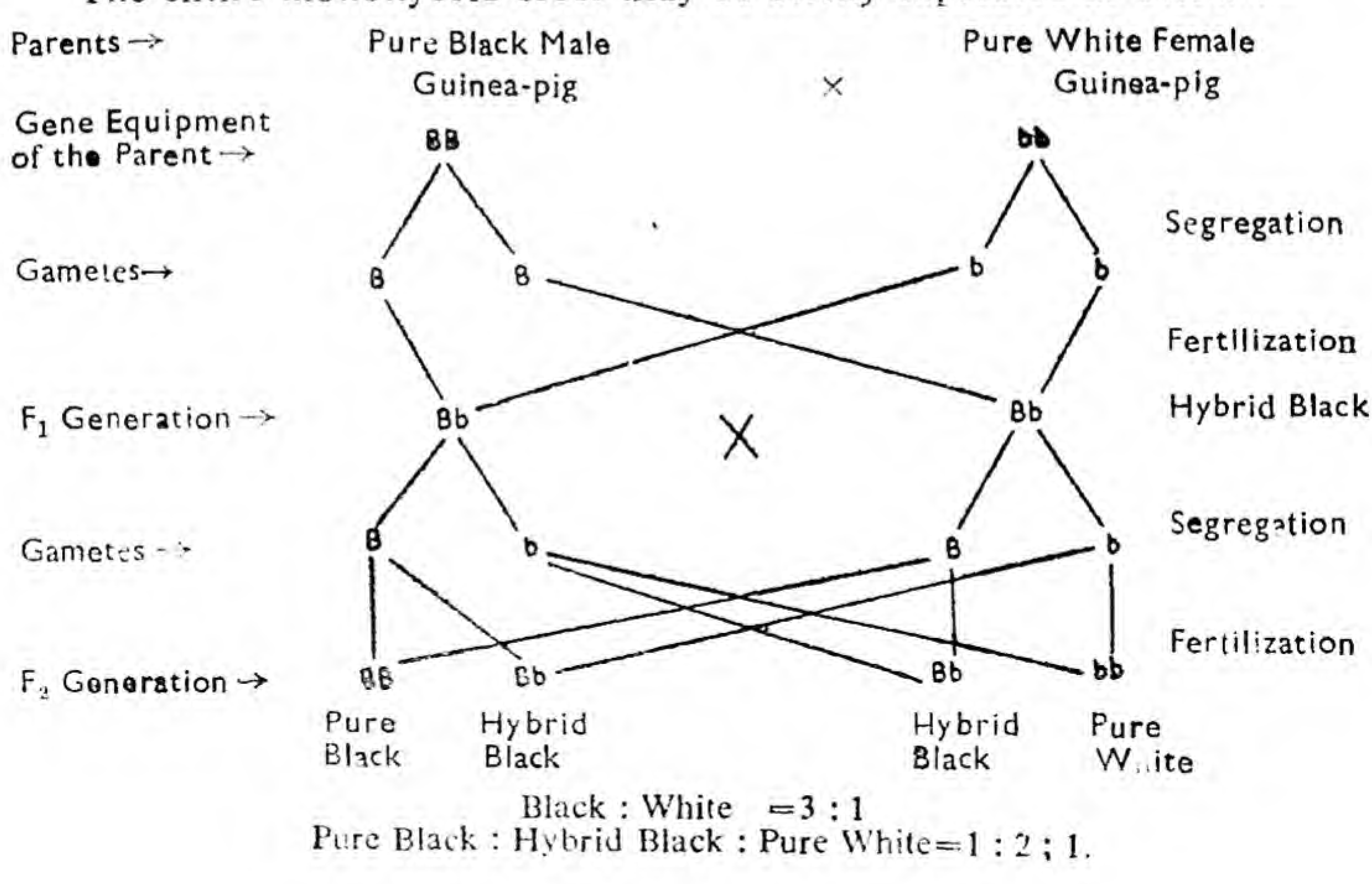
Statement. The law of segregation states that during the formation of gametes, the two genes of each character separate leaving only one gene of each character in each gamete. Since the gametes possess one gene of each character, they are always pure. This law is, therefore, also called the **law of purity of gametes.**

Explanation. This law can be explained with the help of a **monohybrid cross,** *i.e.* a breeding experiment in which only one character is considered at a time. Select a pure black male guinea-pig and cross it with a pure white female guinea-pig. Here the black colour is

dominant over the white colour. Since each character is represented by two genes and in a pure individual both the genes of a character are similar, the gene equipment of these parents will be BB and *bb* where B stands for the gene of dominant black colour and *b* for the gene of recessive white colour. During the formation of gametes, there occurs reduction division which involves the separation or segregation of homologous chromosomes and genes. The two genes of the black colour will separate during sperm formation and the two genes of white colour will likewise separate during egg formation. The gene equipment of the sperms and eggs will, thus, be B and *b* respectively. Now there will be fertilization or fusion of the gametes. The zygote formed from a sperm with a gene of black colour B and an egg with a gene of white colour *b* will possess two unlike genes B*b*. The gene for black colour, being dominant, will express itself in the individual and the gene for white colour, being recessive, will remain unexpressed. All the offspring in the first generation, called the **first filial** (L. filious=son ; filia=daughter) or **F_1 generation**, will therefore, be black. They resemble the male parent to look at but genetically they differ from both the parents as they are hybrid or heterozygous.

Now cross the hybrid black males and females of F_1 generation. The genes of black and white colour will segregate at the time of gamete formation and will recombine at the time of fertilization according to the law of chance. In the second or F_2 generation, the offspring will be in the ratio of three blacks to one white. Of the blacks, one-third are pure for black colour and two-thirds are hybrid black. The whites are all pure. In other words, the pure black, hybrid black and pure white appear in the ratio of 1 : 2 : 1 in F_2 generation.

The entire monohybrid cross may be briefly expressed as below :—



Black : White =3 : 1

Pure Black : Hybrid Black : Pure White=1 : 2 ; 1.

The above cross shows the behaviour of the genes of a single character The genes of all other characters behave in the same manner. (Fig. 38.1).

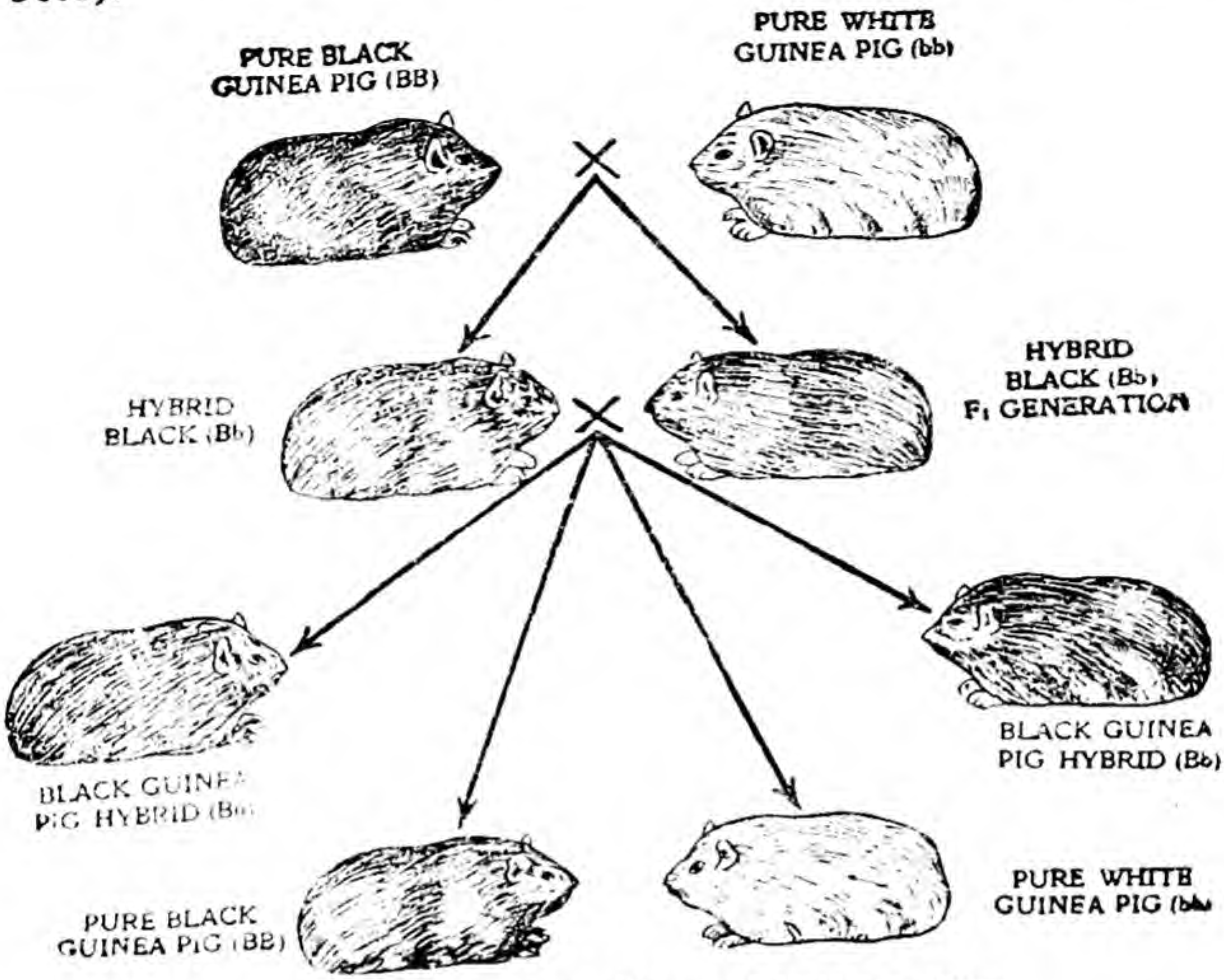


Fig. 38.1. A monohybrid cross between a pure black Guinea-pig and a pure white Guinea-pig.

2. Law of independent Assortment of Genes

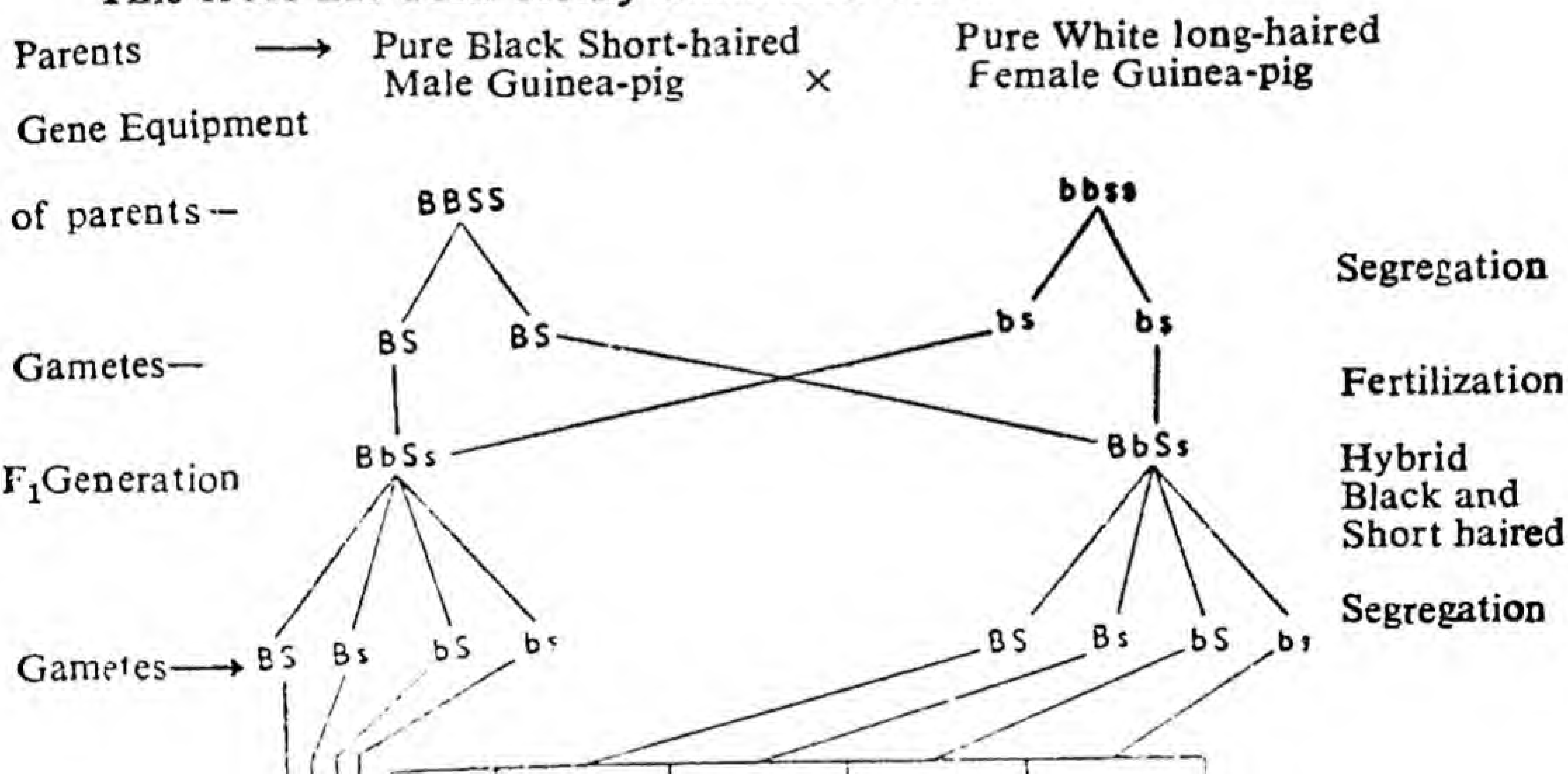
Statement. This law states that the genes of different characters are independent of one another in their behaviour during gamete formation and in the subsequent expression in the individual.

Explanation. This law can be explained with the help of a **dihybrid cross**, *i.e.* a breeding experiment in which two characters are dealt with simultaneously. Mate a pure black short-haired male guinea-pig with a pure white long-haired female guinea-pig. Here the black colour is dominant over the white colour and the short hair are dominant over the long hair. Since each character is represented by two genes and both these genes are similar in a pure individual, the gene equipment of the parents can be taken as BB SS and *bb ss* respectively where B stands for the gene of dominant black colour, *b* for the gene of recessive white colour, *S* for the gene of dominant short hair and *s* for the gene of recessive long hair. During the formation of gametes, there occurs reduction division in which two genes of each character segregate so that a gamete has only one gene of each character. With the result, the gene equipment of the male and female gametes in this cross will be BS and *bs* repectively. Now fertilization occurs. The zygote comes

to possess two unlike genes of coat colour and two unlike genes for the size of the hair, *i e*. it has *Bb Ss*. The offspring developed from such zygotes will be all hybrids with black colour and short hair.

Now cross the hybrid black short-haired males and females of F_1 generation among themselves. The genes for black and white colour and also for short and long hair again segregate during gamete formation. The gametes show four combinations of genes, *viz*. black short (BS), black long (Bs) white short (*bS*) and white long (*bs*). These gametes on fertilization produce four types of guinea-pigs in F_2 generation. They are in the ratio of nine black short, three black long, three white short and one white long. The black and white are in the ratio of 3 : 1 and pure black, hybrid black and pure white are in the ratio of 1 : 2 : 1. Similarly the short-haired and long-haired guinea-pigs show a ratio of 3 : 1 and pure short-haired, hybrid short-haired and pure long-haired a ratio of 1 : 2 : 1.

This cross has been briefly illustrated below



F_2 generation

	BS	Bs	bS	bs
bs	BbSs	Bbss	bbSs	bbss
bS	BbSS	BbSs	bbSS	bbSs
Bs	BBSs	BBss	BbS	Bbss
BS	BBSS	BBSs	BbSS	BbSs

F_2– ⟶Black : white=12 :4 or 3 :1.

Pure Black : Hybrid Black : Pure White—4 : 8 : 4 or 1 : 2 : 1

Short haired : Long-haired 12 : 4 or 3 : 1.

Pure short-haired : Hybrid Short haired : Pure Long-haired =4 : 8 : 4. or 1 : 2 : 1.

This dihybrid cross dealing with two characters simultaneously yields the same results as in a monohybrid cross, namely,

(1) in F_1 generation raised from two pure parents, all offspring are alike and resemble the parent with dominant characters superficially;and

(2) in F_2 generation, the dominant and recessive characters appear in the ratio of 3 : 1.

This proves that the genes of different characters do not interfere with each other's behaviour but are sorted out independently of each other.

Incomplete Dominance or Blended Inheritance

The characters or genes are not always dominant or recessive. In certain cases, the hybrid produced by crossing two pure individuals does not resemble either of them but is midway between them. This is known as **incomplete dominance** or **blended inheritance**. It is due to the fact that the dominant character or gene is not in a position to completely suppress the recessive gene. A good example of incomplete dominance is afforded by the colour of short-horned cattle. A cross between a pure red male animal and a pure white female animal yield hybrids with roan colour, *i.e.* showing red and white patches, in F_1 generation. The roan hybrids on crossing with each other give the usual Mendelian ratio, *viz.* one red, two roan and one white for every four cattle. In other words, the ratio for F_2 generation is 1 : 2 : 1.

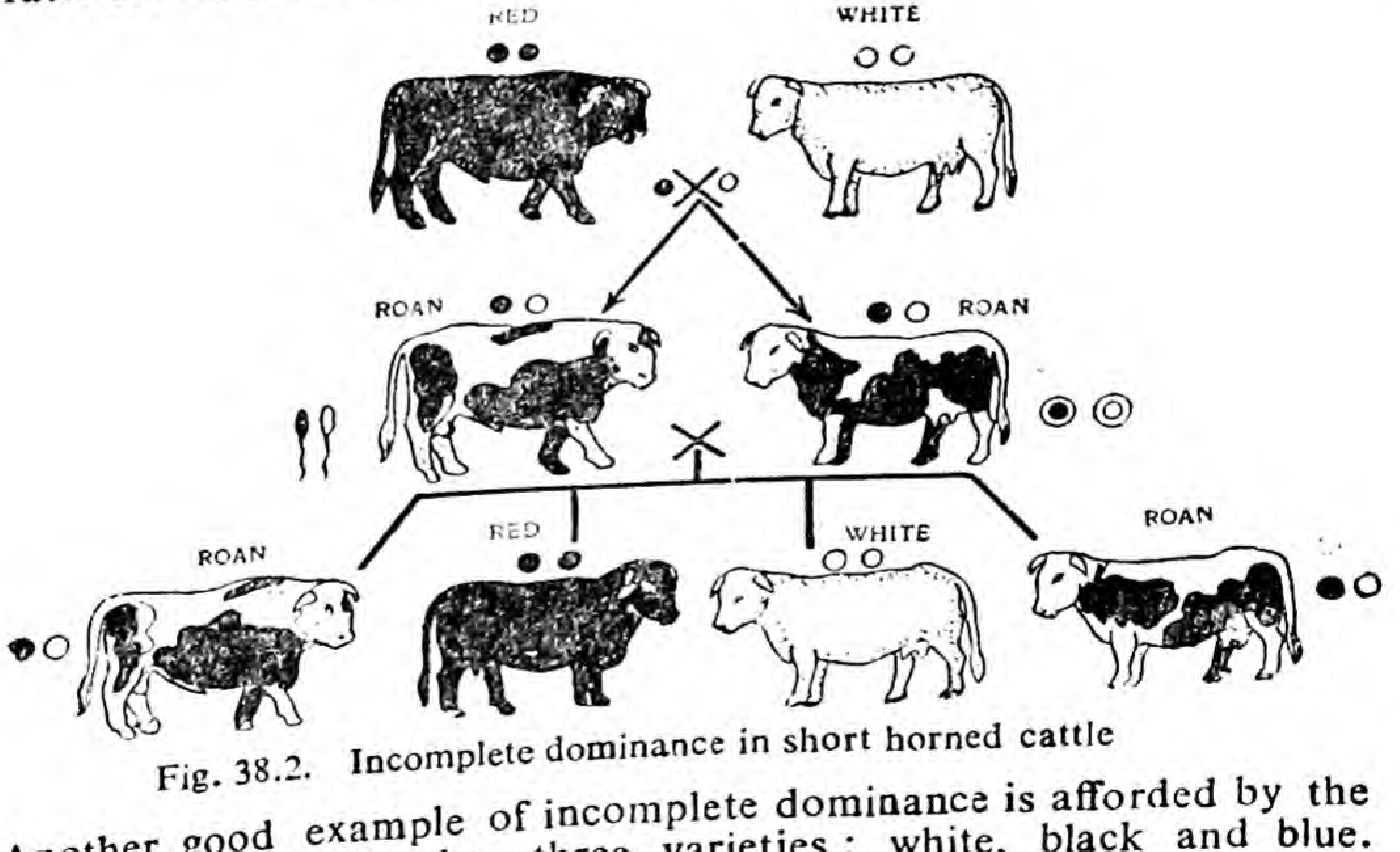


Fig. 38.2. Incomplete dominance in short horned cattle

Another good example of incomplete dominance is afforded by the Andalusian fowl which has three varieties : white, black and blue. (Fig. 38.3). A cross between a pure white male and a pure black female fowls yields hybrid fowls with blue colour in F_1 generation. The blue appearance of the hybrids is due to very fine alternating white and black streaks on the feathers. The blue hybrids on crossing with

each other give the usual Mendelian ratio for monohybrid cross, *i.e.* one white, two blue and one black fowl for every four fowls, *i.e.* their ratio is 1 : 2 : 1.

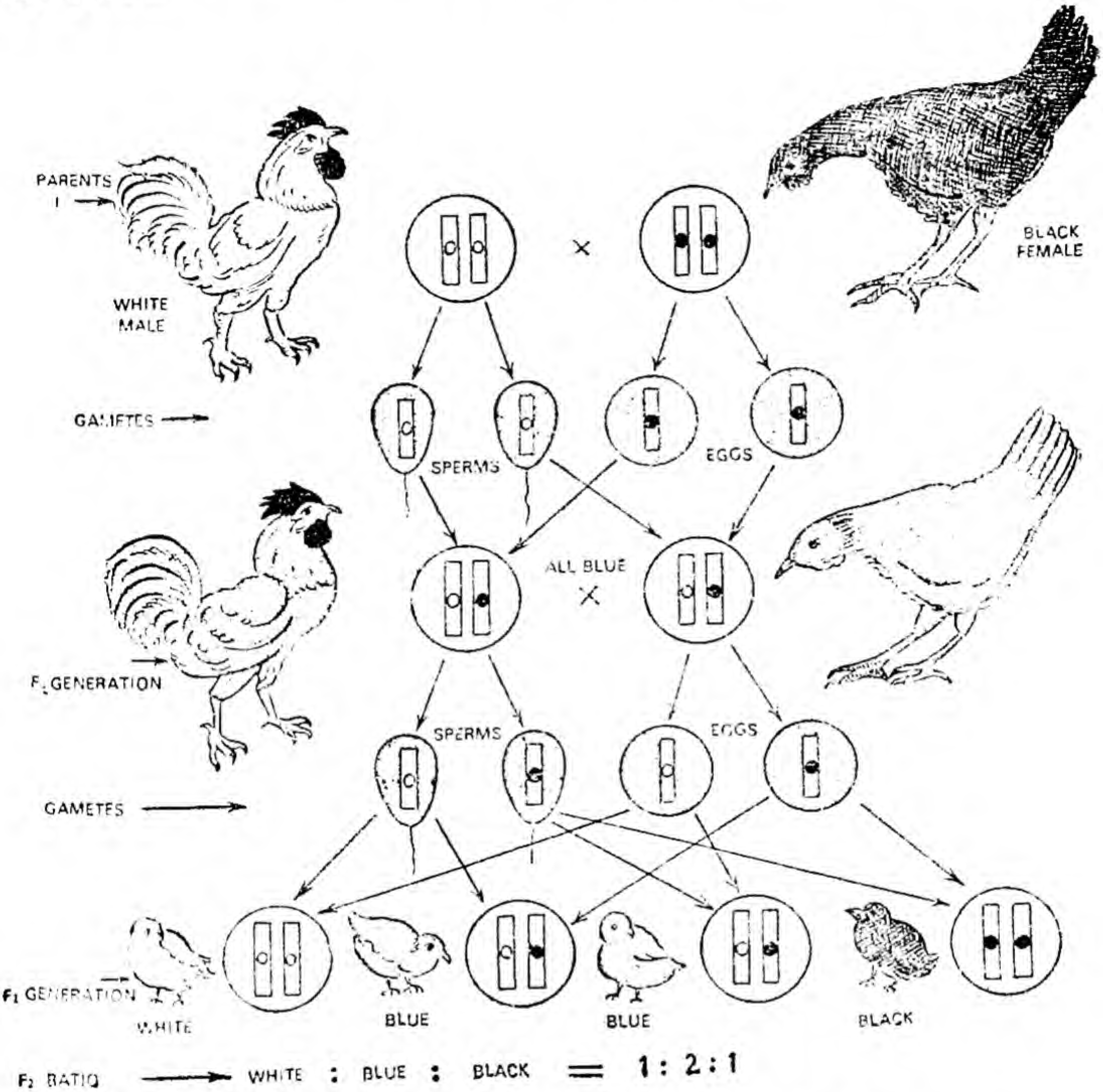


Fig. 38.3. Incomplete dominance in Andalusian Fowl

This case illustrates the practical utility of Mendel's laws of heredity. Of the three varieties of Andalusian fowl, the blues are in demand for food but the blacks and whites are 'wasters', as they are not eaten. In the past the poultrymen have been destroying the blacks and whites and have been crossing the blues, hoping that they would get all blues. They, however, got only 50% blues from such crosses, the other 50% being wasters. We now know that if blacks and whites are crossed, all the offspring are blue. There is, thus, no need of destroying the so-called wasters.

Genetic Principles Discovered After Mendel

Since the time of Mendel, three more genetic principles have been

discovered. These are : **linkage, crossing over** and **linear arrangement of genes.**

1. Linkage. There are always many more pairs of inheritable characters in an individual than there are pairs of chromosomes. Consequently, each chromosome must bear more than one gene. All the genes present on the chromosome segregate as a group and travel together from generation to generation. This tendency of certain genes to stay together in hereditary transmisson is known as **linkage.** This phenomenon was first described by Bateson and Punnett in 1906. It explains why in the fruit fly (*Drosophila melanogaster*) the red eyes and grey body occur in the same individual. The reason is that the genes of red eye colour and grey body colour lie on the same chromosome and, therefore, go together in the gamete and next generation.

Mendel succeeded in discovering his law of independent assortment as, luckily the determiners or factors (genes) of seven pairs of contrasting characters selected by him in garden pea were borne on separate chromosomes and, therefore, assorted in the same way as the chromosomes themselves.

2. Crossing over. Sometimes even the characters linked together due to the presence of their genes on the same chromosome separate, This is brought about by the phenomenon of crossing over. This phenomenon involves the mutual exchange of corresponding parts of the homologous chromosomes (Fig. 38.4). Homologous chromosomes lying side by side in synapsis get twisted around each other, break at corresponding points and exchange corresponding parts. With the result, when they finally separate, they carry different sets of characters.

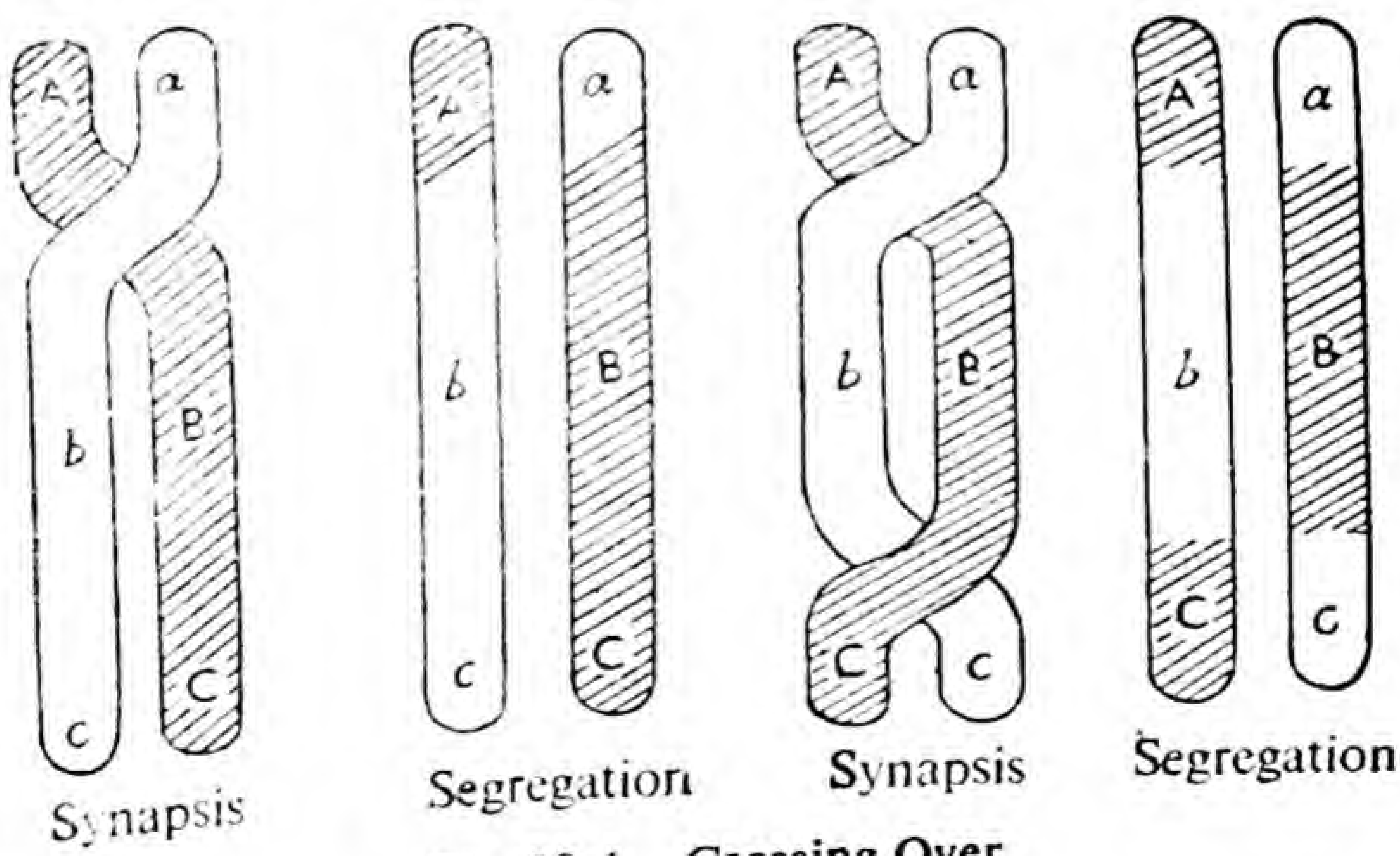


Fig. 38.4. Crossing Over

3. Linear Arrangement of Genes. Breeding experiments have shown that of the genes that make up a linkage group, some undergo crossing over more often than others. The reason is, as first suggested by Sturtevant, that the genes of each linkage group are linearly arranged

on their chromosome and that they maintain their relative positions. Consequently, crossing is likely to occur more often between genes that are far apart on the chromosomes than between those which lie near together. This conclusion of Sturtevant has helped the geneticists to determine the positions (loci) of genes on the chromosomes in *Drosophila* with considerable correctness. This is called **mapping of chromosomes.**

Economic Importance of Mendelism

The knowledge of heredity is of a great practical utility to man.

(*i*) It has enabled man to develop or intensify the desirable characters in an organism and to eliminate the undesirable traits. With this technique, man has improved the form and yield of the domestic animals, food crops, fibre plants and fruit trees.

(*ii*) The principles of heredity apply equally well to mankind. They can help in the improvement of human race if proper laws of marriage are formulated and obeyed.

(*iii*) The knowledge of heredity has also helped the study of evolution and has dispelled many faulty notions about inheritance.

TEST QUESTIONS

1. Define heredity. Enunciate and explain the Mendel's laws of heredity.
2. Define the following terms—

   Allelomorph, Pure or Homozygous animals, Hybrid or Heterozygous animals, Dominant character, Recessive character, Monohybrid cross, Incomplete dominance, F_1 generation, Homologous chromosomes.
3. Describe a cross showing incomplete dominance.
4. What is the Mendel's second law of heredity ? Explain this law from a cross between two Andalusian fowls.
5. Discuss the practical utility of Mendel's laws of heredity.
6. Name and explain genetic principles discovered after Mandel.

CHAPTER 39

Organic Evolution

(Evidences)

It has been noted in the chapters dealing with the general survey of the animal kingdom that there are myriads of different types of animals in the universe. The same is true about the plants. We are now to find out how all these various forms of life have come into existence. There are two main views about it : the theory of special creation and the doctrine of organic evolution.

I. **Theory of special Creation**. According to this theory, life has been created by some supernatural power, the **creator** or **God**. There are three important points in this theory :—

(*a*) All the animals and plants were created simultaneously without any relationship with one another.

(*b*) They were created in the same form in which they exist to-day, *i.e.* each animal or plant is a fixed entity incapable of undergoing change.

(*c*) Their organs have been specially designed to meet the needs of the environment in which they have been created.

This theory is not based on scientific data and it does not explain many biological phenomena. It has, therefore, been rejected.

II. **Doctrine of Organic Evolution.** The doctrine of organic evolution postulates that the present complex animals and plants have been produced in the course of ages by a process of gradual change in the earlier simpler forms of life. This may be briefly expressed as 'descent with modification'. According to this view, the acellular organisms were the first among the animals to appear in the world. Some of them gave rise to the multicellular animals. The earlier multicellular animals were invertebrates of various types. Some invertebrates were later modified into the early vertebrates, *i.e.* fishes. The fishes gradually changed into the amphibians. Certain amphibians then produced the reptiles. Some of the latter were finally evolved into birds and mammals.

The idea of change in the living organisms. *i.e.* evolution, is a very old one. It was, however, not considered seriously for a long time. During the past 100 years or so, it has gained a considerable hold on the rational minds and it now enjoys almost a universal acceptance.

This is because a lot of evidence has accumulated in its favour. The exact mode of evolution, *i.e.* the way in which one animal or species changes into another, is still not very clear and even to-day there are different views about it. We shall first discuss the evidences to prove that evolution has actually taken place and then review in the next chapter the possible ways by which it may have occurred.

Evidences of Evolution

There are five main types of evidences which support the doctrine of organic evolution. These are anatomical, embryological, palaeontological, physiological and genetical.

1. Anatomical Evidences. Anatomy is the study of internal structure of animals as revealed by dissection. The aspects of anatomy which provide evidences for evolution are classification, homologous structures, connecting links, vestigial organs and atavism.

(*i*) **Classification**. The natural classification of animals and plants is based on the comparison of their structures. The individuals showing certain similarities are put together in one group. The smaller groups resembling one another in some features are combined into a larger group and so on. The similarities within a group and between various groups suggest that there is a definite relationship between the various forms of life. The vertebrates like fish, frog, lizard, pigeon and rabbit beautifully illustrate this relationship. These animals look very different from one another but they all resemble in having a dorsal hollow central nervous system, a ventral heart, a notochord and gill-slits. This similarity in the outwardly different animals cannot be without any significane. It indicates their common ancestry.

Further, the various groups of the animals and plants can be arranged in an order showing gradually increasing complexity in structure. This shows that they have appeared in this very order, the lower forms developing into the higher ones by gradual modification. The gradual modification is exhibited by the heart and the ear of the vertebrates. The heart is two-chambered (one auricle and one ventricle) in the fishes, three-chambered (two auricles and one ventricle) in the amphibians, incompletely four-chambered (two auricles and partly divided ventricle) in most of the reptiles and completely four-chambered (two auricles and two ventricles) in birds and mammales. The fishes possess internal ear only, the amphibians have developed middle ear also. the reptiles have added external ear which becomes better develop in the mammals.

Had there been creation, the various animals would have been altogether different from each other and it would not have been possible for us to classify them at all.

(*ii*) **Homologous Organs.** The organs which look very different and perform different functions but have the same fundamental structure are called the homologous organs (Fig. 39.1). The fore-limbs of vertebrates like frog, lizard, pigeon, bat, whale, horse and man afford a good example of the homologous organs. The fore limbs of these animals have

different shapes and serve different purposes. They are used for leaping in the frog, for creeping in the lizard, for flying in the pigeon, for swimming in the whale, for running in the horse and for grasping in the man. They are, however, built on the same plan. In each case, the fore-limb consists of the upper arm having a single bone, the **humerus** ; fore-arm containing two bones, **radius** and **ulna** ; and the hand having **carpals** in the wrist, **metacarpals** in the palm and **phalanges** in the digits. This basic similarity in the structure of the apparently different limbs is due to the fact that all these limbs have been evolved from a common

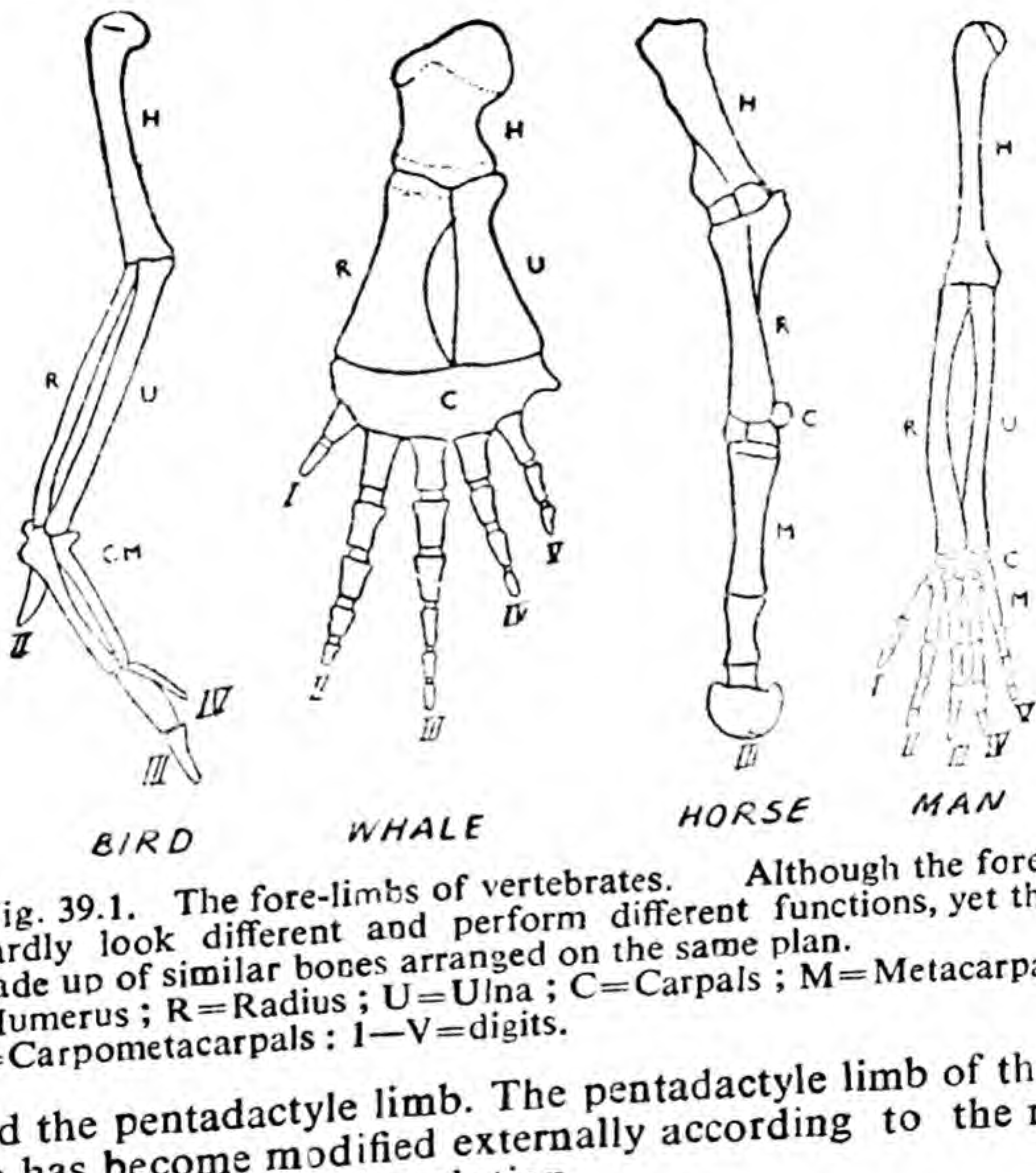


Fig. 39.1. The fore-limbs of vertebrates. Although the fore-limbs outwardly look different and perform different functions, yet they are all made up of similar bones arranged on the same plan.
H=Humerus ; R=Radius ; U=Ulna ; C=Carpals ; M=Metacarpals
CM=Carpometacarpals : I—V=digits.

type called the pentadactyle limb. The pentadactyle limb of the ancestral vertebrate has become modified externally according to the need of the animal during the course of evolution.

Another example of the homologous organs is seen in the mouth-parts of insects. In all the insects, the mouth-parts include a labrum, a pair of mandibles and two pairs of maxillae. But these are differently modified in different insects. This modification is associated with the feeding habit of the insect. In cockroach the mouth-parts are adapted for chewing solid, in mosquito for sucking liquid food, in house-fly for sponging fluids, and in the butterfly for siphoning nectar. The similarity in the fundamental structure of the apparently different mouth-parts indicates the common ancestry of all insects.

The homologous organs, therefore, prove that there has been evolution and not creation.

(*iii*) **Connecting Links.** The living animals which possess characters of two different groups of animals are known as the connecting links. The lung-fishes serve as a connecting link between the fishes and the amphibians. They, besides having all the characters of fishes, possess a single or double lung for breathing air like the amphibians. They indicate the way in which the fishes were modified into the amphibians.

The egg-laying mammals like spiny ant-eater and duck-billed platypus provide another example of the connecting links. They link the mammals with the reptiles. They are decidedly mammals as they have many mammalian features like hair, mammary glands, diaphargm, single aortic arch, etc. But they resemble the reptiles in having a large coracoid in the pectoral girdle and in laying large eggs with yolk and shell. They are, thus, midway between the reptiles and the mammals and are sometimes described as the unfinished mammals. They show the stages through which the reptiles have evolved into mammals.

The connecting links establish continuity in the series of animals by proving that one group has been evolved from the other.

(*iv*) **Vestigial Organs.** The organs which occur in reduced form and are useless to the possessor but correspond to the functional organs of related animals are called the vestigial organs. The existence of vestigial or useless organs is not explained by the theory of special creation according to which all the organs of the animal have been specially designed to meet its needs. The doctrine of organic evolution, on the other hand, offers a very satisfactory explanation for the presence of useless organs in the animals. These organs were fully developed and functional in the ancestral forms from which the present day form have been evolved. But due to change in the mode of life of the existing forms, they have gradually become reduced and functionless.

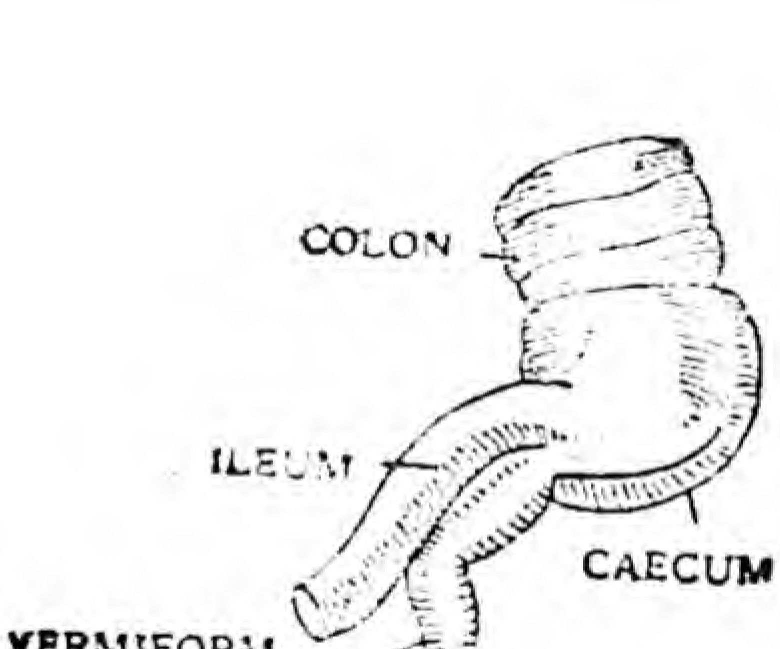


Fig. 39.2. Vermiform appendix in man

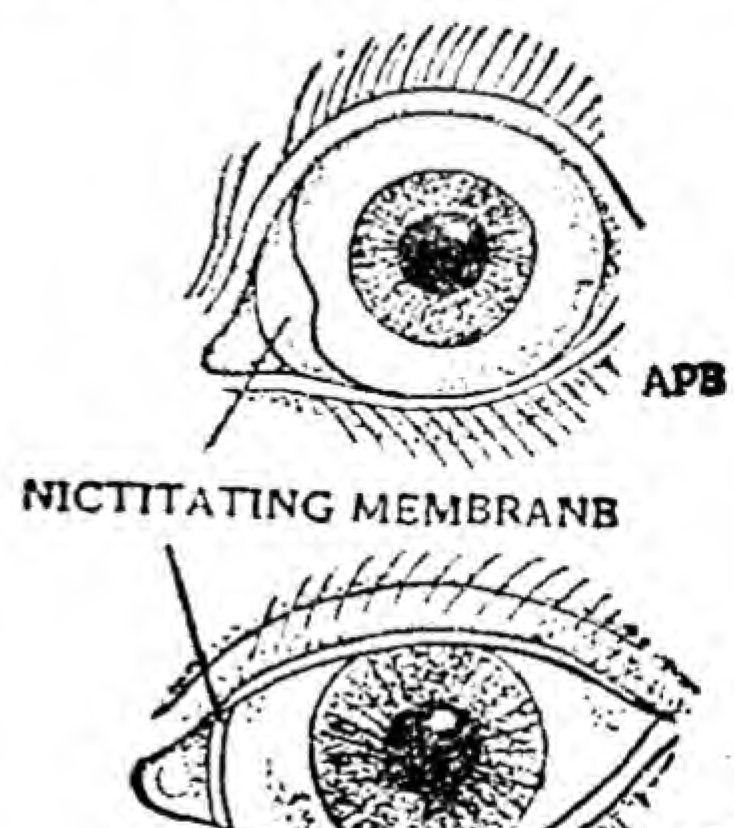


Fig. 39.3. Nictitating membrane

There are many vestigial organs in man, *e.g.* third eye-lid or nictitating membrane (Fig. 39.3.), muscles of the pinna (Fig. 39.4), vermiform appendix (Fig. 39.2), etc. The vestigial organs are found in other animals also like the hip-girdles and bones of the hind-limbs in

some whales and pythons, splint bones in the horses and wings in the flightless bird called kiwi.

In most of the vertebrates, the third eye-lid (Fig. 39.3) is well-developed and is moved across the eye at intervals for cleaning the cornea. In man cornea is cleaned by the upper eye-lid. Consequently, the third eye-lid has become reduced and non-functional in the course of time.

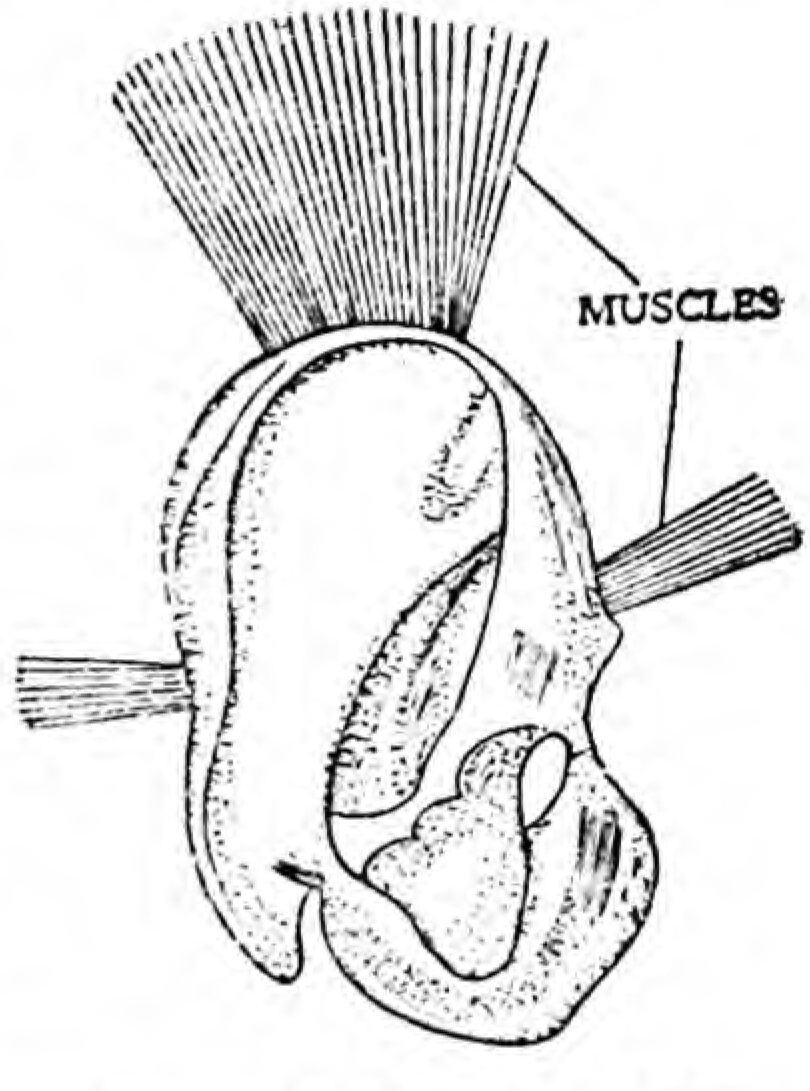


Fig. 39.4. Muscles of the pinna in man.

Mammals possess three muscles in connection with each pinna (Fig. 39.4). With the help of these muscles, they move their pinnae to set them in the direction of sound. These muscles have become reduced and useless in man during the course of evolution. He, therefore, cannot move the pinnae.

Vermiform appendix (Fig. 39.2) is a blind tube at the end of the caecum in certain mammals including man. In herbivorous forms, the caecum and vermiform appendix are large structures and serve for the digestion of cellulose contents of the food by bacterial action. In man the habit of taking soft and cooked food has dispensed with the need for

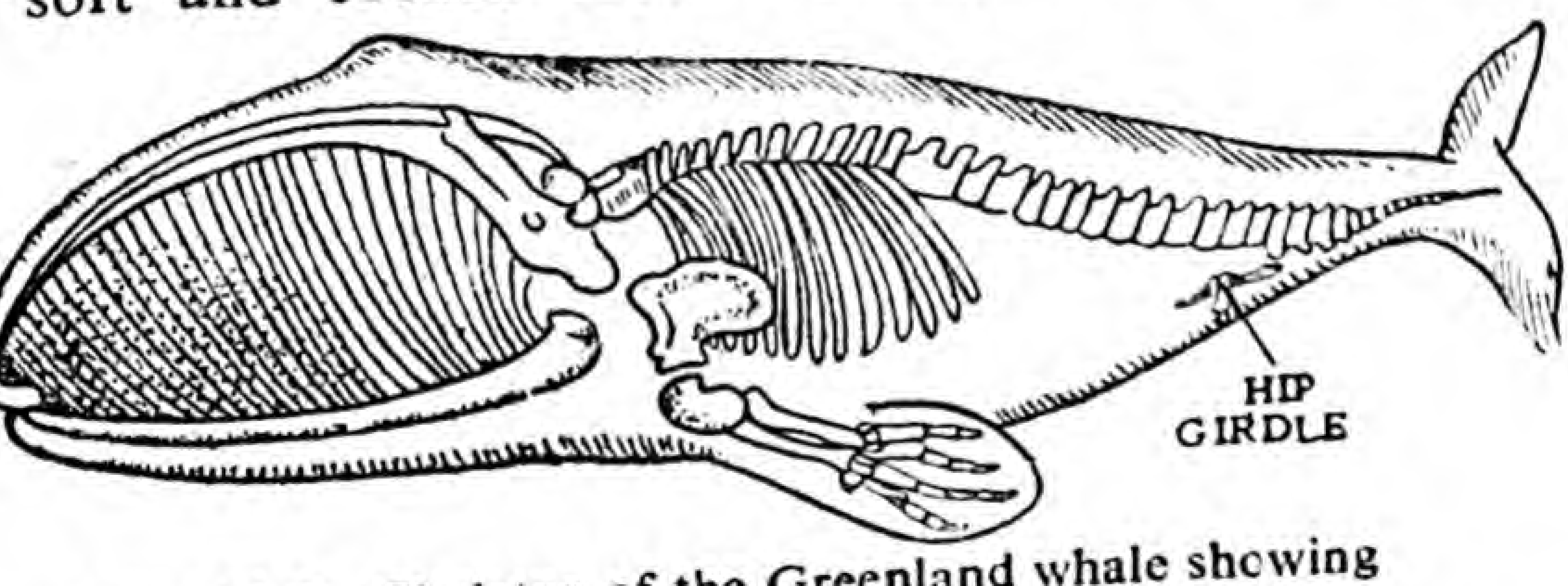


Fig. 39.5. Skeleton of the Greenland whale showing vestigial hip-girdle and bones of the hind-limb.

bacterial digestion. The caecum and appendix have consequently become reduced. They persist because they were present in the ancestral forms. The vermiform appendix sometimes becomes diseased in man. The disease is called appendicitis and requires surgical removal of the appendix.

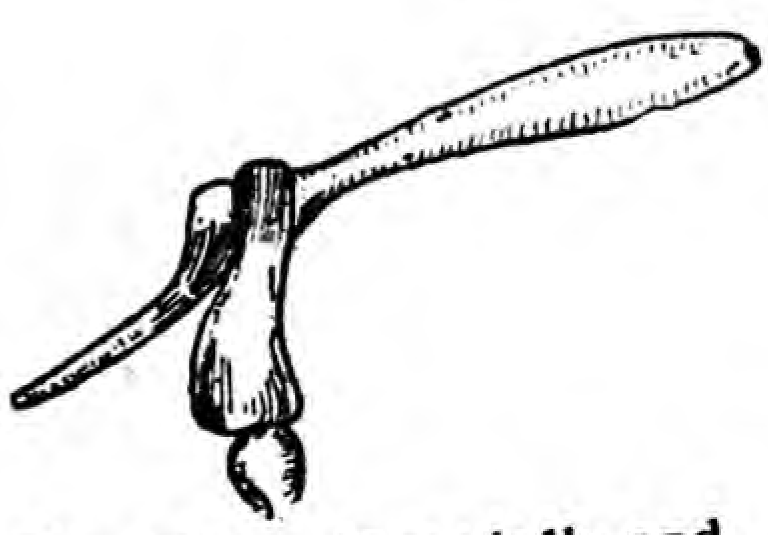


Fig. 39 6. Hip-girdle and bones of the hind-limb of Greenland whale

Whales normally lack pelvic girdles and hind-limbs. The Greenland whales, however, possess vestiges of pelvic girdles and bones of the hind-limbs inside the body (Fig. 39.6). This shows that the whales have been evolved from the forms which

possessed hind-limbs and hip girdles. The latter have become vestigial during evolution in the Greenland whales and have completely disappeared in other whales.

The snakes have been evolved from the lizard like reptiles bearing two pairs of functional limbs but due to change in their mode of life, have lost the limbs completely. The pythons still retain the pelvic girdles and the hind-limbs in a reduced condition (Figs. 39.7 and 39.8).

The splint bones in the limbs of horse (Fig. 39.11) are the vestiges of the functional toes of its ancestors.

(*v*) **Atavism.** Atavism, also called reversion, the reappearance of certain ancestral, not parental, structure which has either completely disappeared or greatly reduced. There are many examples of atavistic

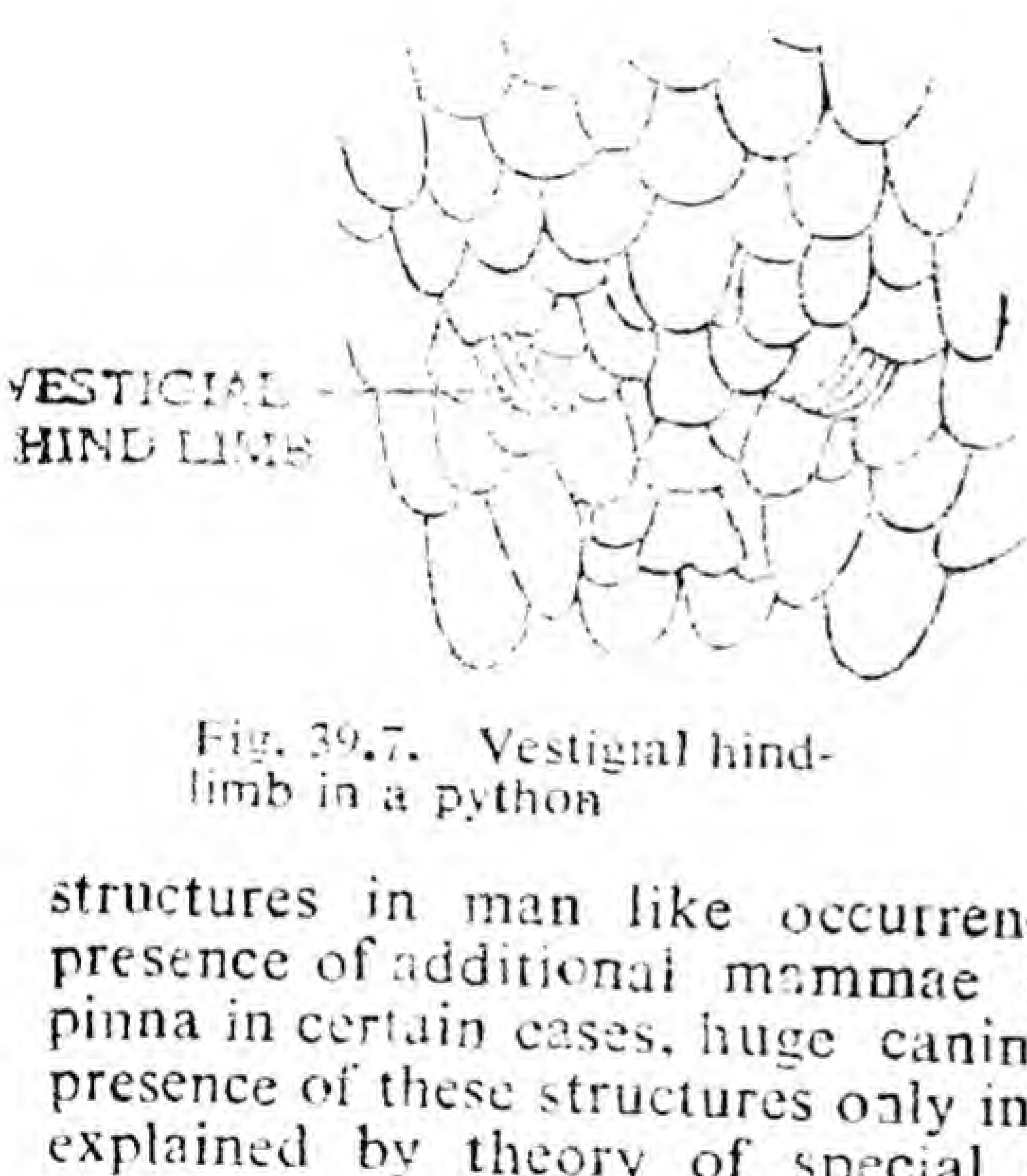


Fig. 39.7. Vestigial hind-limb in a python

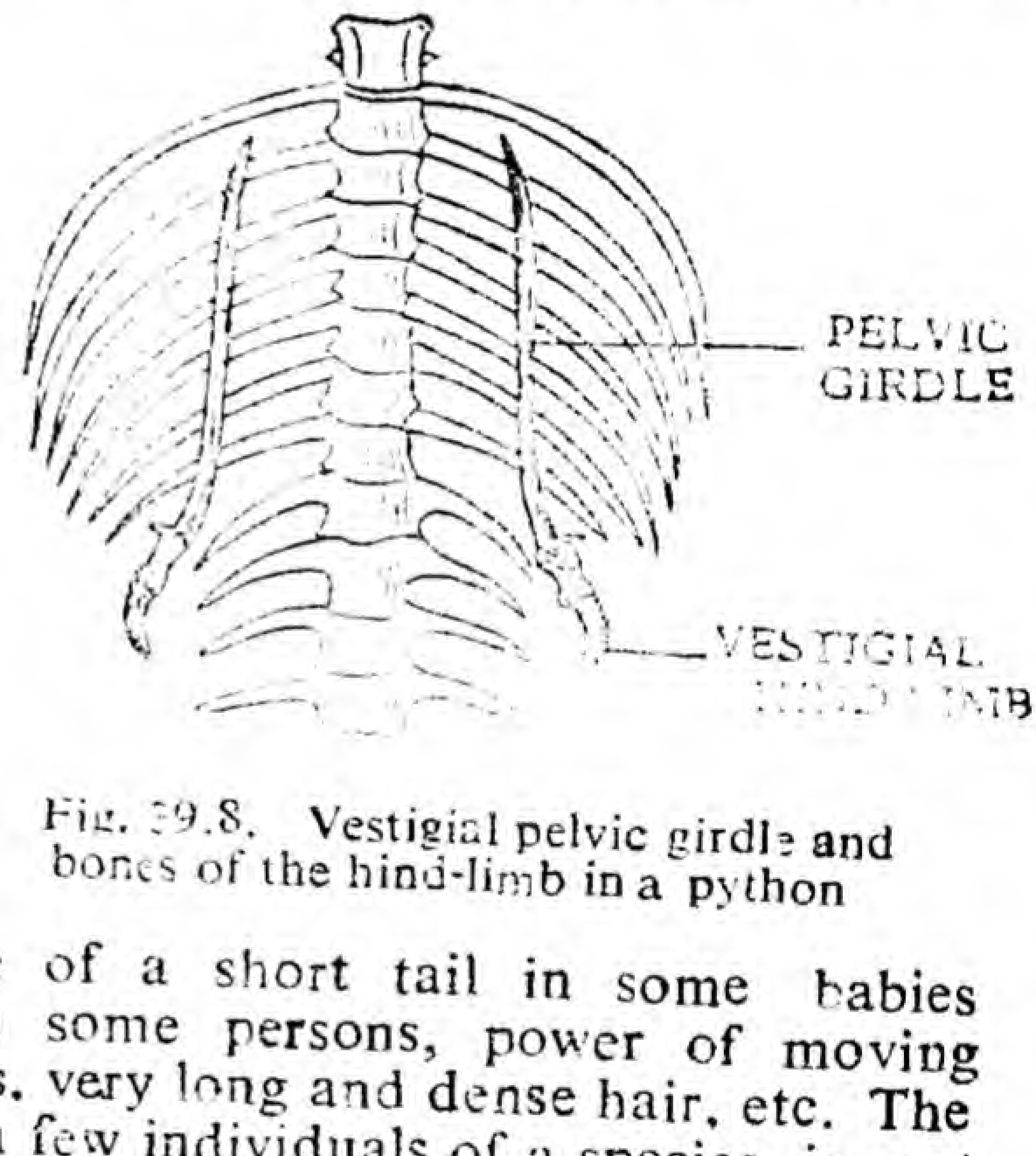


Fig. 39.8. Vestigial pelvic girdle and bones of the hind-limb in a python

structures in man like occurrence of a short tail in some babies presence of additional mammae in some persons, power of moving pinna in certain cases, huge canines, very long and dense hair, etc. The presence of these structures only in a few individuals of a species is not explained by theory of special creation according to which all the individuals of a species should be alike. They can be explained on the assumption that there is a tendency among the animals to develop structures of their remote ancestors.

2. **Embryological Evidences.** Embryology is the study of development of animals from egg to adult. The aspects of embryology which lend support to the doctrine of organic evolution are : similar early development in all the animals, similarity in the embryos of vertebrates, biogenetic law, temporary embryonic structures and development of organs.

(*i*) **Similar Early Development.** Every multicellular animal, from *Hydra* to man, begins its life from a single cell, the fertilized egg or zygote. In all cases, the zygote undergoes **segmentation** producing a mass of cells, the **morula**. The morula changes into a single-layered hollow structure,

the **blastula.** The latter then develops into a two-layered **gastrula.** The outer layer of the gastrula is called the **ectoderm** and the inner the **endoderm.** The two-layered or **diploblastic** animals like, *Hydra* and *Obelia* stop their development at this stage. They simply grow in size and become adult. In three-layered or **triploblastic** animals, the gastrula develops another layer, the **mesoderm,** in-between the ectoderm and endoderm. The embryo, thus, becomes three-layered. The entire animal develops from these three layers which are called the primary germ

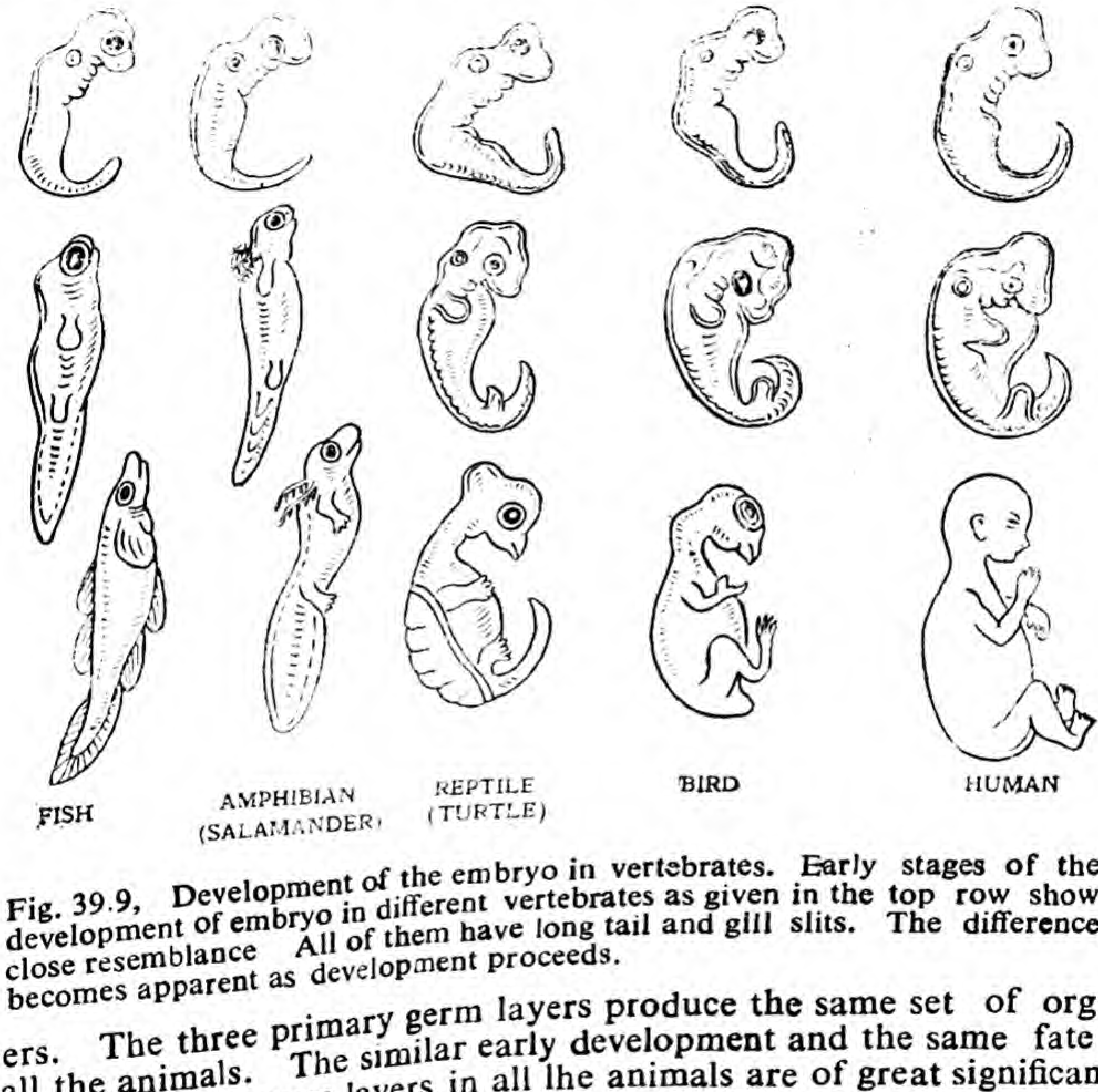


Fig. 39.9, Development of the embryo in vertebrates. Early stages of the development of embryo in different vertebrates as given in the top row show close resemblance. All of them have long tail and gill slits. The difference becomes apparent as development proceeds.

layers. The three primary germ layers produce the same set of organs in all the animals. The similar early development and the same fate of the three primary germ layers in all lhe animals are of great significance. They establish a close relationship among the **Metazoa** and suggest that all of them have been evolved in a series from a common ancestor.

(*ii*) **Similarity in the Vertebrate Embryos.** The embryos of all the vertebrates are similar in shape and structure in their early stages (Fig. 39.9). The resemblance is sometimes so close that it becomes difficult to tell them apart. This similarity among the vertebrate embryos is a proof of the common ancestry of all the vertebrates. Besides this, the resemblance of the embryos also indicates the evolutionary relationship of the adult vertebrates. The embryos of the vertebrates nearer to each other

in the adult stage resemble more and for a longer period than the embryos of the vertebrates far away from each other in the adult stage. For instance, the embryos of a mammal and a reptile will resemble more and for a longer duration than the embryos of a mammal and a fish.

(iii) **Biogenetic Law**. Biogenetic law, also called **recapitulation theory**, was put forward by Von Bear in 1828. It states that every animal in its development briefly repeats the evolutionary history of its race. It may be briefly stated **ontogeny** repeats **phylogeny**. Ontogeny is the life-history of an individual from egg to adult while phylogeny is the evolutionary history of the race of an animal. All the vertebrates start their life from a single cell, the zygote. All of them during their life-history pass through a two-layered gastrula stage and then through a fish-like stage with gill-slits. They do so because they have descended from the Protozoa through coelenterate-like and fish-like ancestors and they are to repeat these evolutionary stages in their life-history.

(iv) **Temporary Embryonic Structures.** The embryos of birds develop teeth which disappear before hatching. The embryos do not take any food through the mouth. They live on yolk which is absorbed by special blood-vessels. Their teeth are, therefore, of no use to them. The adult birds feed on hard solid food like grains, nuts, meat, etc. and require teeth for mastication but they have none. This is a peculiar phenomenon. A structure is present when not needed and disappears when its need arises. The theory of special creation has no explanation for this strange case. It can, however, be explained from the belief that :—

(*a*) the birds have been formed by modification of toothed reptiles,

(*b*) they have lost teeth in the course of modification and

(*c*) their embryos repeat the ancestral character of the presence of teeth.

(*v*) **Development of Organs**. The development of certain organs in the vertebrates indicates their common ancestry. The heart is one of such organs. During its development in birds and mammals, it first becomes two chambered, then three-chambered and finally four-chambered. This indicates that both birds and mammals have originated from the fishes which have two-chambered heart through the amphibians and reptiles which have three-chambered heart.

The development of brain also suggests the common origin of all the vertebrates. In all cases it arises as enlargement of the anterior part of the nerve-cord in the embryo (Fig. 28.1). This enlargement in all cases gets divided by two grooves into three regions, namely, fore-brain, mid-brain and hind-brain. Each of these three parts develops further more or less in a similur manner till the adult condition is reached.

Why should the heart and brain of such remote animals like rabbit and frog develop in a similar way ? The answer lies in their common origin. The theory of special creation has no explanation for it.

3. **Palaeontological Evidences.** Palaeontology is the study of past life based on the fossil record. The fossils are the petrified remains or impressions of the ancient animals and plants preserved in the rocks.

Palaeontology furnishes the most direct and reliable evidence for evolution as it deals with the actual organisms that lived in the past. Before considering the ways in which Palaeontology supports evolution, it is necessary to know how the fossils are formed and studied.

Our earth came into existence as a molten mass. It was probably cast out from some other heavenly body. Its surface gradually cooled down and solidified. This gave rise to the solid crust of rocks enclosing a molten centre. With the loss of heat from the earth, the water vapours of the atmosphere condensed and filled the depressions on the surface of the crust. This produced the oceans and the seas.

The rocks formed by the solidification of the originally molten earth are called the **igneous rocks**. These rocks have been gradually breaking down under the influence of rain, wind, heat, cold, etc. The broken-down particles of these rocks have been carried by the rivers to the oceans where they have been settling at the bottom layer after layer. The new rocks formed in this manner at the ocean-floor are known as the **stratified** or **sedimentary rocks**. During the formation of these rocks, the dead animals of the sea and of the land carried to the sea by rivers, have been sinking down and getting burried in the rocks. These animals, thus preserved in the rocks, have formed the fossils. Geological upheavals have raised many of the stratified rocks above the surface of the sea, thus, bringing their preserved life or fossils within human reach.

Man has taken out many animals from the stratified rocks accessible to him but his knowledge of fossils is still very meagre. In fact, it can never be perfect due to certain reasons. The marine forms have a greater chance of being preserved in the rocks. Many animals have died on land, never reaching the occean for fossilization. Only the hard parts of the animals can be preserved in the rocks. The soft parts decay and disappear. Thus, the animals without hard parts have left no fossil record. The fossils, being situated at the sea-floor, are not accessible for study. The fossils in the deeper rocks have been destroyed by the pressure of the overlying strata and by excessive heat. Even the rocks which have been exposed by upheavals cannot be explored fully. Last of all, the study of the fossils is very difficult.

It has been estimated that the age of our earth is near about 300 crore years, possibly even more. Life first appeared in water about 200 crore years ago. The duration of the earth's history has been divided into six principal geological time-spans called the **eras**. Of these, the three more recent eras are further divided into smaller spans known as the **periods** which are in turn split up into **epochs**. The geological time-scale indicating the sequence and duration of the eras and periods with their dominant forms of life is shown in the table No. 28.

Let us now derive evidences for evolution from palaeontology. The aspects of palaeontology which support evolution are : the distribution of fossils in the rocks, disparity between the present and the past forms of life, missing links and ancestries of individual animals.

(*i*) **Distribution of Fossils in the Rocks**. The distribution of fossils in the rocks of different ages fully agrees with the concept of evolution. The

TABLE 28. Time-scale of Earth
(To be read from below upwards)

Eras	Age From present	Periods	Dominant Forms of Life
Psychozoic	About 10,000,000 yrs.	Recent	**Age of man** Modern man, mammals, birds and insects.
Cenozoic (Era of recent life)	About 70,000,000 yrs.	Quarternary.	**Age of Mammals** Great mammals become extinct. Higher mammals remain dominant. Primitive man becomes common.
		Tertiary	Archaic mammals become extinct. Higher mammals appear and become dominant. Primitive man appears.
Mesozoic (Era of mediaeval life)	About 200,000,000 yrs.	Late Mesozoic	**Age of Reptiles** Great reptiles become extinct. Birds and mammals appear. Toothed birds disappear.
		Early Mesozoic	Reptiles increase and become dominant. Bony fishes appear. Toothed birds appear.
Palaeozoic (Era of ancient life)	About 500,000,000 yrs.	Late Palaeozoic	**Age of Amphibians** Amphibians maximum. First reptiles appear. Modern insects, sea-lilies and urchins abundant. Trilobites become extinct.
		Middle Palaeozoic	**Age of Fishes** Fishes maximum. Invertebrates abundant. Amphibians appear. First air-breathing animals, like, insects appear.
		Early Palaeozoic	**Age of Invertebrates** Marine invertebrates maximum (sponges, jelly-fishes trilobites, mollusks, star-fishes, corals, etc). Fishes appears.
Proterozoic (Era of early life)	About 1,450,000,000 yrs.		Simple marine invertebrates without shell appear. Fossils scanty.
Archeozoic (Era of dawn of life)	About 2,000,000,000 yrs.		Acellular forms appear. No. fossils.

fossils progress from simple to more complex types as we come from the earliest to the more recent rocks. The rocks of the earliest eras,namely, archeozoic and proterozoic, do not show fossils. The fossils begin from the palaeozoic era. In the early part of this era are found the fosssils of marine invertebrates. In the rocks of the middle and later parts of this ear, appear the fossils of fishes and amphibians respectively. In the rocks of the next era, the mesozoic, are found the fossils of great reptiles and primitive birds and mammals. Finally, the recent era, the cenozoic, shows fossils of typical mammals in the early part and of apes and man in the later part (Table No. 28).

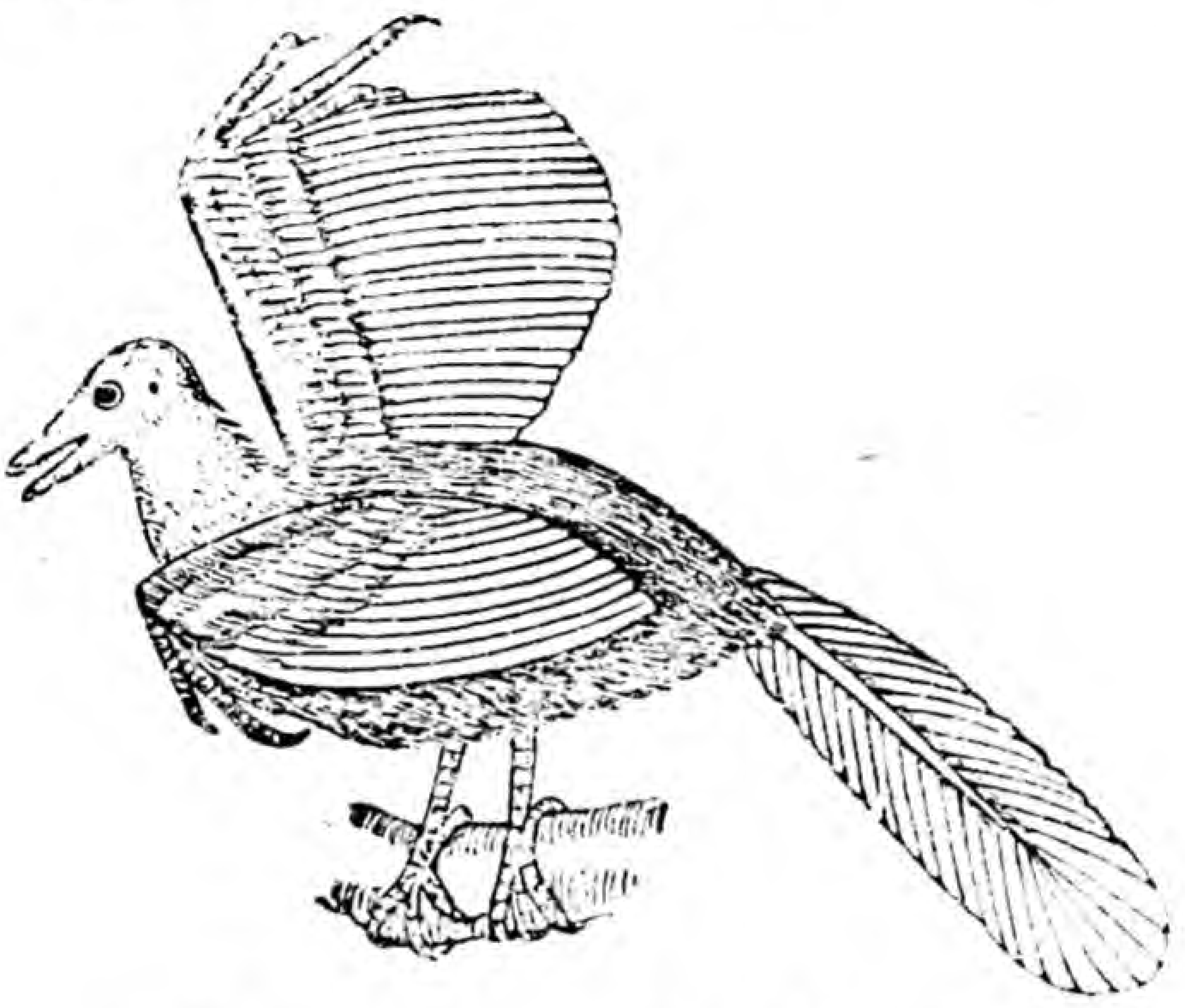


Fig. 39.10. *Archaeopteryx* (After Romanes).

(*ii*) **Disparity between the Past and the Present Forms of Life.** There is a lot of difference between the extinct animals and their living allies, *e.g.* the extinct reptiles (Dinosaurs) were enormous creatures as compared with the existing ones. The early man was different from the modern man. He lived in the caves like animals and had no social life. He lived by hunting and by gathering fruits and seeds of wild plants. By several changes, both in form and structure, he has developed into the modern civilized man. It, thus, follows that life has been changing ever since it appeared. This is against the theory of special creation.

(*iii*) **Missing Links.** The fossils which show characters of two different groups of living animals are called the missing links. An excellent case of such a link is afforded by the fossil bird *Archaeopteryx* (Fig. 39.10). It was decidedly a bird as it possessed feathers which are exclusively avian structures. But like the reptiles, it had teeth in the jaws, claws on free fingers, a long tail bearing tail feathers on the sides and a keelless sternum. This bird represents a stage midway between the reptiles and birds and suggests, the path of evolution of the latter from the former.

(*iv*) **Ancestries of Individual Animals.** Though there are several difficulties in the formation and study of fossils, complete evolutionary

histories of animals like horse, camel and elephant have been traced from the fossils by the palaeontologists. The evolution of horse is shown in the Fig. 39.11. The modern horse belongs to the genus *Equus*. Its evolution has been traced to an animal which lived about 6 crore years back in the beginning of the cenozoic era. This dawn horse is called *Eohippus*. It was a small animal, about the size of a fox. Its fore-limbs had four toes each and the hind-limbs had three toes each. Its molar teeth were small and constructed for grinding. About 2 crore years later, it changed into an animal called *Mesohippus*. *Mesohippus* had three toes on each foot. It was of the size of a goat. After another one crore years, another animal called *Merychippus* was formed. It was of the size of a

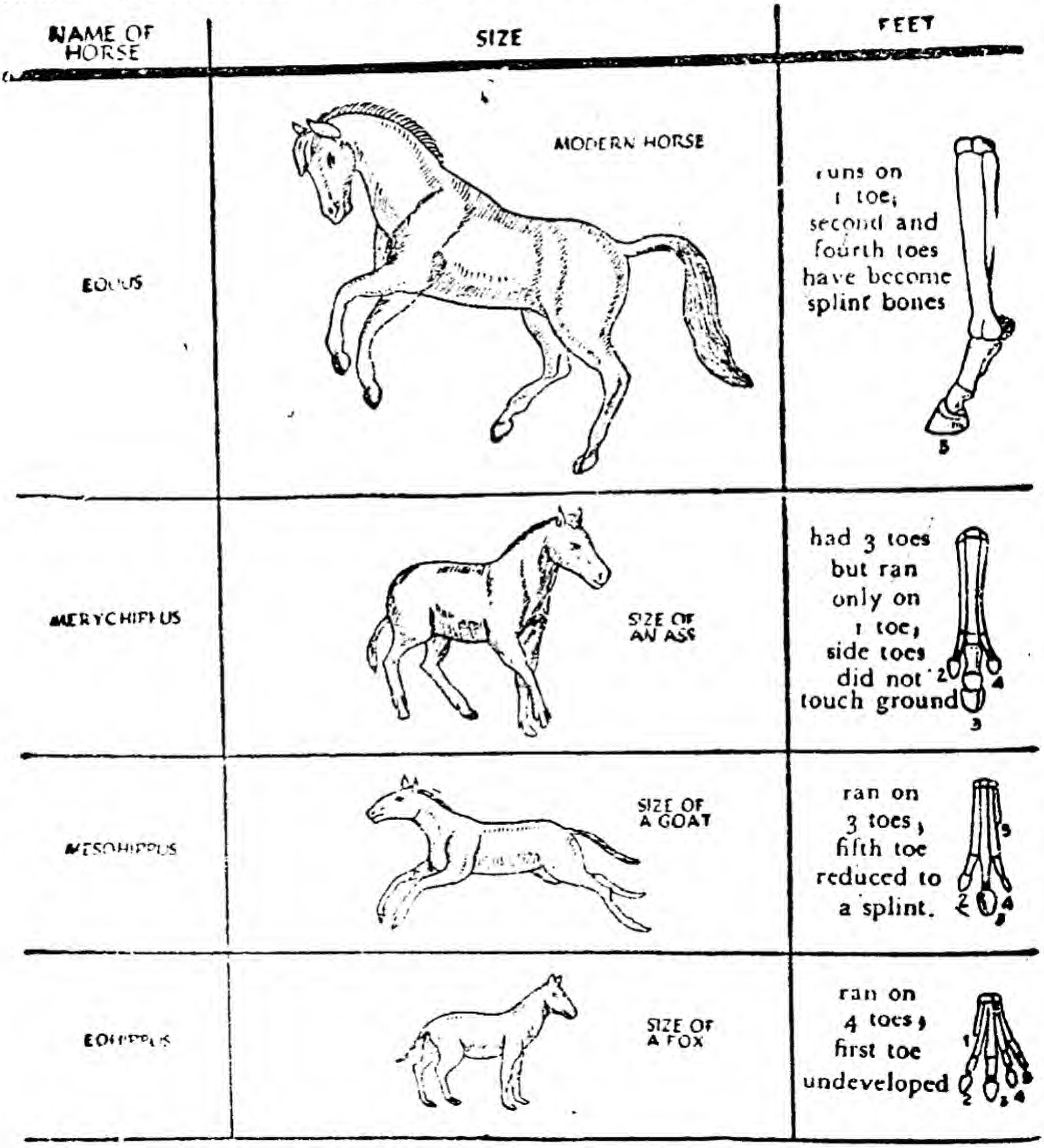


Fig. 39.11. Evolution of the horse from a four toed animal to the modern horse through the ages. The number of fingers in the last column corresponds to the number of fingers on the hands of man.

modern ass. Like *Mesohippus*, it had three toes per foot but it could run only on one toe. The two side toes had become much smaller and did not touch the ground. Its molar teeth had ridges and were suited for chewing and grazing on grass. The modern horse has descended from this animal. It appeared first as a fossil about 5 lakh years ago. It has only one toe on each foot and the two side toes are reduced to splint bones.

From the above evolutionary history of the horse, we can safely conclude that all other animals have been evolved in a similar way.

4. **Physiological Evidences.** Physiology is the study of the functions of living bodies. It has been noted in the anatomical and embryological evidences that similarity in structure and development of animals suggests a close relationship among them and points to their common ancestry. The same is true about the similarity in the physiological processes of animals. The aspects of physiology which establish kinship among the animals are : protoplasm, deoxyribonucleic acid, enzymes, hormones, blood and lymph and chemical reactions.

(*i*) **Protoplasm.** Protoplasm has a similar physical and chemical composition throughout the living beings—plants as well as animals. This similarity establishes relationship in the world of life.

(*ii*) **Deoxyribonucleic Acid**. The chromosomes of all cellular organisms, whether they are plants or animals, are always composed of deoxyribonucleic acid or DNA and this DNA replicates itself in a similar manner in all. This uniformity further highlights theinter-relation-ship of all organisms.

(*iii*) **Enzymes.** The digestive enzymes are essentially alike in their nature and action throughout the vertebrates. They can be taken from one animal and safely administered to another. The enzymes are often taken from the sheep, pig, cattle, etc. and used in medicines. This shows that all the vertebrates are related to one another.

(*iv*) **Hormones**. The hormones, *i.e.* secretions of ductless glands, resemble in their chemical nature and function in all the mammals. The similarity is so close that the deficiency of insulin hormone in man can be made up by giving him the pancreas of other animals.

(*v*) **Blood and Lymph**. The blood and lymph fluids are almost similar in their composition and physiological role in all the animals.

(*vi*) **Chemicals Reactions**. Chemistry of digestion, respiration, muscle contraction and transmission of nerve impulses is almost similar in all animals.

The similarity in the physiological processes of the animals shows that all of them have a common origin.

5. **Evidence from Animal Breeding.** Man has been able to produce new varieties of useful animals by hybridisation and artificial selection. Several breeds of dogs, horses, sheep, cattle, etc. have been produced. For getting new breeds, man has simply been copying one of the natural methods by which new types of animals have been evolved. If man can

produce new breeds in a short period, nature with vast resources and infinite time at its disposal can easily bring forth new species.

TEST QUESTIONS

1. Define the doctrine of organic evolution. Enumerate the evidences in favour of this doctrine. Discuss the one which in your opinion is the most convincing.

2. Explain the following terms :—

Fossil, Homologous Organs, Vestigial Organs, Phylogeny, Ontogeny, Connecting Links, Palaeontology, Stratified Rocks, Embryology, Missing Links.

3. How will you account for the following :—

(*a*) Frog passes through a fish-like stage in its life-history.

(*b*) The embryos of birds have teeth.

(*c*) Duck-bill resembles both reptiles and mammals.

(*d*) The fore-limbs of all vertebrates are basically alike.

(*e*) Animals have certain useless structures.

4. Explain the formation of fossils. Name the great eras of the earth's history and state what animals were characteristic of each.

CHAPTER **40**

Organic Evolution

(Theories)

The fact that there has been evolution in the living world has been fully established. The opinions, however, differ on the way in which evolution has taken place. These are—

1. Lamarck's theory of the inheritance of acquired chararcters or Lamarckism.
2. Darwin's theory of natural selection or Darwinism.
3. De Vries' mutation theory.

Jean Baptiste de Lamarck

Lamarackism

This is the first theory of evolution. It has been put forward by a well-known French biologist named Jean Baptist de Lamarck (1744—1829). He published it in 1809 in his Philosophic Zoologique.

Factors of the Theory. Lamarck's theory is based on three factors, namely, new needs, acquisition of characters. and inheritance of acquired characters.

(*i*) **New Needs.** Change in the environment of an animal creates new needs for it. The animal has to put in special efforts for the fulfilment of its new needs. These efforts lead to a change in the habits or behaviour of the animal. The new habits involve fresh or extensive use of certain organs of the body and disuse of others.

(*ii*) **Acquisition of Characters.** Characters are acquired by the use and the animals in two ways : disuse of organs and by effects of environment.

(*a*) **Use and Disuse of Organs.** Use and disuse of organs affect their form, structure and mode of functioning. Continuous use of organs keeps them active and makes them larger and stronger. Permanent disuse of organs gradually make them weaker so that they finally disappear.

(*b*) **Environmental Factors.** The environmental factors like variations in temperature, light, medium, food, etc. also affect the living things and produce changes in their bodies.

The changes brought about by use and disuse of organs and by the influence of environmental factors in an individual during its life time are called the **acquired characters.**

(*iii*) **Inheritance of Acquired Characters.** The characters acquired by an individual as explaind above are transmitted by heredity to the next generation. In every generation fresh characters are acquired. With the result, after a number of generations, the species is modified into a new one.

Explanation of the Theory. Evolution of animals according to Lamarck's theory may be explained by citing a few examples from his own writings.

(*i*) **Giraffe.** Giraffe is a mammal with very long neck and long fore-limbs. It has evolved from an ancestor with small neck and small fore-limbs. This ancestor happened to live in a barren place where leaves of the trees were the only food available to it. In making an effort to reach the leaves, it continuously stretched its neck and fore-limbs. This resulted in slight elongation of these parts. The increase was transmitted to the next generation in which further elongation occurred due to similar efforts. This process, after a number of generations, produced the present-day giraffe.

(*ii*) **Aquatic Birds.** The aquatic birds (ducks, swans, etc.) are considered to have arisen from the terrestrial ancestors. They spread their toes widely and stretched the skin at their base in order to rest on water. This gradually developed a web between the toes.

(*iii*) **Snakes.** The ancestors of the snakes were lizard-like reptiles with two parts of fully-developed limbs. These ancestors, out of fear of the mammals, which were larger and more powerful,started living in narorw crevices or holes and thick vegetation. In this effort they stretched their body to accommodate it in a narrow space and did not use the limbs. Continuous stretching of the body made it longer and slender while permanent disuse of the limbs caused their disappearance.

(*iv*) **Deer.** The deer is thought to have developed its present speed through continuous efforts of running to which it resorted for protecting itself from its enemies.

Criticism of the Theory. Lamarck's theory cannot be accepted fully. Its first two factors are correct. New needs are created by a change in the environment and new characters are acquired by use and disuse of organs and environmental factors. The 3rd factor, *i.e.* inheritance of the acquired characters is, however, disputable. There is evidence both against as well as in favour of the inheritance of acquired characters.

(a) Evidence Against the Inheritance of Acquired Characters. A German biologist, August Weismann (1834–1914), offered the greatest opposition to the inheritance of acquired characters. He put forward his **theory of the continuity of the germplasm**. According to this theory, a multicellular animal consists of two types of cells : the **germ cells** which contain determinants for all the hereditary characters in their nuclei and the **somatic cells** which harbour in their nuclei only the characters of a particular organ. The environment and use and disuse of organs affect the somatic cells only. They have no influence on the germ cells. This means that the acquired characters reside only in the somatic cells. The variations in the somatic cells have no effect on the germ cells. The somatic cells are mortal and perish with the death of the animal. Thus, the acquired characters vanish when the individual bearing them dies. The germ cells are immortal and are passed on intact from generation to generation. It, therefore, follows that the acquired characters are not inherited.

Weismann's view holds good in many cases. He cut off tails of rats for about 80 generations but tailless rats were never born. Boring of external ear (pinna) has been practised by the Indian women for several generations but this character has never been inherited. The athletes develop powerful muscles by continued use but they are not transmitted to the offspring. Pavlov, a Russian physiologist, trained mice to come for food on hearing bell and found that training was necessary in each generation. All these examples prove that the characters acquired by an individual during its own life time are not inherited by the next generation.

(b) Evidence in Favour of the Inheritance of Acquired Characters. Weismann's theory has its dark side also. Sometimes the somatic cells produce the germ cells which is against this theory. This is seen during vegetative propagation in plants and regeneration in animals. A purely somatic stem cutting sprouts in to a new plant which bears flowers having germ cells. A part without reproductive organs cut off from the body of an earthworm into a complete individual which develops the re-productive organs or germ cells. Similarly, Driesch has shown theory that a segment of an embryo meant for the production of somatic cells can be made to develop into a complete embryo. These examples indicate that the somatic cells also contain the determinants of all the characters. Only then they can give rise to the germ cells. This has been shown to be true by the cytologists in the recent years.

Recently certain experiments have shown that environment can affect the germ cells and hence inheritance. Tower exposed some potato beetles to abnormal conditions of temperature and humidity at the time of the development of their reproductive organs. This did not produce any change in the beetles themselves. Their offspring, however, exhibited colour variations which were passed on to the succeeding generations. X-rays and certain chemicals also produce inheritable variations.

The instances against Weismannism and experiments showing the influence of environment on heredity have revived the otherwise discarded Lamarckism. This revival is called **Neo-Lamarckism**.

Taking all the fore-going cases into consideration, it may be said that there is more evidence against than in favour of Lamarckism. Lamarckism, consequently, does not provide a satisfactory mechanism for evolution.

II. Darwinism.

The theory of natural selection was announced in 1858 by Charles Darwin and Alfred Russel Wallace, both having arrived at it independently. It was later explained by Darwin in his book "Origin of Species" in 1859. This theory is based on the following factors :—

(*i*) Rapid multiplication,

(*ii*) Limited food and space,

(*iii*) Struggle for existence,

(*iv*) Variations,

(*v*) Natural selection or survival of the fittest.

(*vi*) Inheritance of useful variations, and

(*vii*) Formation of new species.

Charles Darwin

(*i*) **Rapid Multiplication.** All animals and plants reproduce in a fixed geometrical ratio. They produe more offspring than can actually survive. A few examples are cited to illustrate excessive multiplication of individuals.

(*a*) **Paramecium.** *Paramecium* divides three times in 48 hours. With this rate, a single *Paramecium* will produce in five years a mass of *Paramecia* equal to ten thousand times the size of the earth.

(*b*) **Cod.** The cod fish may produce over a million eggs in a year. If all the eggs develop into fishes, in five years, the whole Atlantic ocean will be full of cods.

(*c*) **Elephant.** The elephant is a slow breeder. It lives up to ninety years. It starts breeding at the age of thirty years. During its life time, it produces only six offspring. Yet, if all the young ones survive, a single pair would produce 19,000,000 elephants in 750 years.

In spite of their enormous potentiality in natural conditions, the individuals of species remain more or less constant. This is because the great majority of potential offspring die.

(*ii*) **Limited Space and Food.** Increase of population in animals and plants requires more space and food. The space in the universe

remains constant. The ultimate source of food for all animals and plants is the mineral wealth of the soil. This wealth does not increase or at least does not increase proportionately.

(iii) **Struggle for Existence.** Because of excessive multiplication by the parents and limited space and food supply, there starts a severe competition among the offspring for their requirements. Every individual makes efforts for fulfilment of its basic needs, namely, suitable space to live, food to eat, mate to reproduce and protection from enemies. This competition for the primary necessities of life is called struggle for existence. The struggle for existence is three fold for every individual ;—

(a) **Intera-specific Struggle.** This is the struggle between the individuals of the same species. This is the keenest form of struggle as the needs of the individuals of the same species are identical. This struggle may be examplified by the efforts of two dogs for a piece of meat.

(b) **Inter-specifie Struggle**. This is the struggle between the individuals of different species. This struggle is illustrated by the efforts of a snake for catching a rat and of the rat for escape.

(c) **Environmental Struggle**. This is the struggle of the animals with the changes in environmental factors like heat, cold, drought, flood, storm, famine, light, etc.

(iv) **Variations**. Variation is the law of nature. Every individual varies in some respects from others of its species. Even the offspring of the same parents are never exactly alike except the identical twins. The animal and plant breeders take advantage of the existence of variations. They choose the specimens with desired traits for their breeding experiments. In the same way these variations within a species enable nature to exercise her selection. The individuals, whose variations make them best adapted to their environments, survive while others, which are less adapted or not adapted, perish.

(v) **Natural Selection** or **Survival of the Fittest**. In the struggle for existence, the individuals having more favourable variation overpower those without them or with less favourable ones. Those which overpower survive and leave their progeny behind them. The overpowered ones are destroyed. The competition is so severe that only a few individuals survive out of millions. This sorting out of the individuals with useful variations has been called natural selection by Darwin and survival of the fittest by Wallace. Natural selection keeps an efficient check on the population of animals.

(iv) **Inheritance of Useful Variations.** The individuals, after their selection by nature in the struggle for existence, pass on their useful variations to the next generation. Darwin did not differentiate between continuous and discontinuous variations. He held that any variation which is favourable to its possessor could be inherited. His inheritable variations included even the acquired characters. In this respect Darwin agreed with Lamarck.

(*vii*) **Formation of New Species.** It has been pointed out that the favourable variations are transmitted to the offspring. These variations become more and more prominent in each succeeding generation. After a number of generations the variations become so marked that their possessor turns into a new species. New species, thus, arise by gradual modification of the older ones.

Summary of the Theory

	Factors	Consequences
I.	1. Rapid Multiplication 2. Limited Food and Space	Struggle for Existence
II.	1. Struggle for Existence 2. Variations	Natural Selection Or Survival of the fittest
III.	1. Natural Selection 2. Inheritance of useful variations	Formation of new Species

Criticism of the Theory. Darwin's theory of natural selection is to-day recognized as the main factor in the evolution of animal and plant life. It, however, has evidence both for and against it.

(*i*) **Artificial Selection.** A close parallelism exists between natural selection and artificial selection. Man, in breeding experiments on useful animals, selects individuals with desired traits and separates them from those which do not possess such characters. The selected ones are permitted to mate among themselves. After repeating this process for the few generations, a new breed of the animal is formed. In this way man has been able to produce several varieties of domestic animals like dogs, horses, pigeons, poultry, cows, sheep, pigs, etc. from their wild ancestors. If man can produce new varieties or breeds in a short period, nature with its vast resources and very long time at its disposal can easily produce new species by selection.

(*ii*) **Mimicry and Protective Colouration.** The remarkable cases of mimicry and protective colouration found in certain animals are the product of natural selection. They could reach their present stage of perfection only by gradual change side by side with the evolution of models and predators.

(*iii*) **Corelation between Nectaries of Flowers and Proboscis of Insects.** Position of nectaries in flowers is wonderfully related to the length of the proboscis of the insects that pollinate them. This relation between two different organisms cannot develop suddenly. It can evolve only gradually as envisaged by the theory of natural selection.

(*b*) **Evidence against the Theory.** The theory does not explain certain facts of life. Darwin himself confessed, "Natural selection has

been the main but not the exclusive means of modification." The points not explained by the theory are—

(*i*) **Inheritance of Small Variations.** Darwin held that small variations form the raw material for evolution. This means that organs appear as small structures and gradually become perfect after several generations. There are certain organs which can be helpful to the animal only in the fully developed condition, *e.g.* wing of a bird. It is difficult to understand the inheritance of such organs in their initial stage when they cannot be of any advantage to their possessor. It is doubtful if the appearance of wings as small structures could enable the ancestral reptile to fly and thus give it any advantage for selection.

(*ii*) **Perpetuation of Vestigial Organs.** According to the theory of natural selection, only the useful organs are selected to the struggle for existence. The vestigial organs serve no function, yet they are being preserved generation after generation.

(*iii*) **Over-specialization of Organs.** In certain animals some organs have developed beyond the stage of usefulness, *e.g.* antlers of deer, tusks of elephants, etc. These organs, instead of proving useful to their possessors, offer hindrance in their daily life. There is no room for their selection in Darwin's theory.

(*iv*) **Lack of Reasons that Produce Variations.** Darwin's theory simply states that the nature selects individuals with useful variations. But what causes the variations is not explained by it. The factors that bring about variations are obviously the primary cause of evolution and must be included in the theory. Thus, natural selection is merely a restrictive and directive factor rather than a creative one.

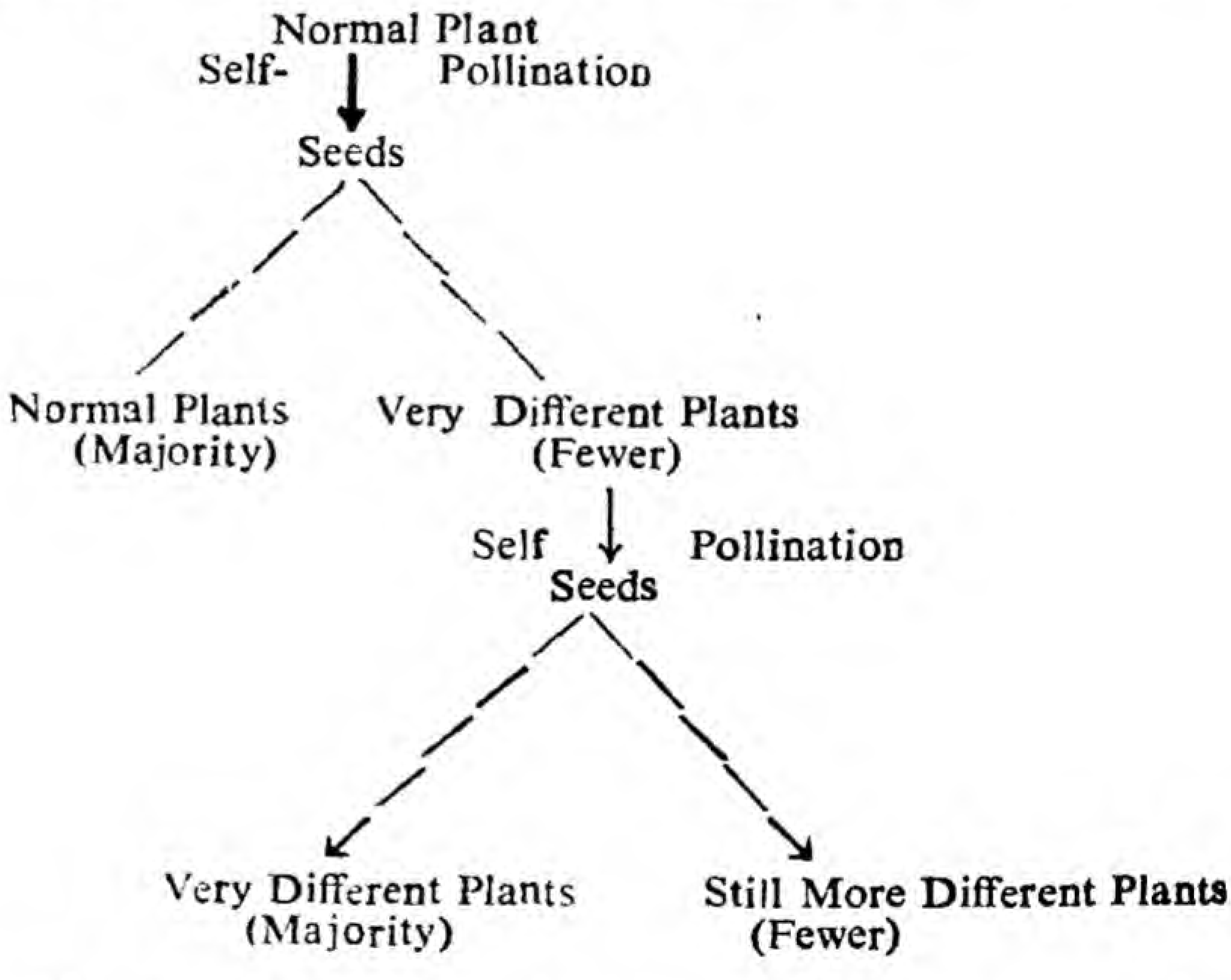
Since Darwin's theory of natural selection did not explain certain facts, scientists started looking for some alteration in the theory to meet its objections. In 1894, William Bateson published his "Materials for the Study of Variations". In this book he suggested that evolution occurred with discontinuous variations rather than with continuous variations as held by Darwin Darwinism with this modification may be called Neo-Darwinism. De Vries also supported this modification in 1901.

III. De Vries' Mutation Theory.

Mutation theory is very recent and convincing too. It was put forward in 1901 by a Dutch botanist Hugo de Vries who lived from 1848 to 1935. According to this theory new species arise from the pre-existing ones in a single generation by the sudden appearance of marked differences called **mutations**. Evolution is, thus, a discontinuous and jerky process rather than continuous and gradual one as held by Lamarck and Darwin. In other words, there is a jump from one species to another.

De Vries was led to formulate this theory from the observations of his experiments on a plant called Evening Primrose (*Oenothera lamarc-*

kiana) which grew wild near his garden. He observed that among the numerous normal plants of Evening Primrose having small variations, there were a few with wide departures from the normal type. He took a normal plant and raised its seeds by self-pollination. On growing these seeds, he found that the majority of the plants were normal like their parent and showed only minor variations. A few were, however, quite different from the parent in many characters. The markedly different plants were found to breed true. They gave rise to a few still more different plants in each generation. From this De Vries held that the new types were appearing in Evening Primrose and that he was actually seeing evolution going on. He called the marked differences 'mutations' and the plants bearing them 'mutants'. He found that the mutations appeared suddenly and were inherited by the offspring. His experiments are briefly expressed below :—



Criticism of the Theory. Like other theories of evolution, mutation theory also has points both in favour of and against it.

(*a*) **Evidence for the Theory.** Mutations do occur in nature in the way held by De Vries. A few examples of mutations which appeared suddenly in a fully developed state are mentioned below :—

(1) The Ancon sheep, a short-legged variety of sheep, was produced by an ordinary sheep in a single generation in 1891.

(2) The hornless or polled Hereford cattle were produced by normal cattle in 1889 in a single generation.

(3) The hairless cats, dogs and mice have arisen from the normal parents in a single step.

All these mutation are inheritable.

(*b*) **Evidence against the Theoy.** The main short-coming in the mutation theory is that the mutations are of rare occurrence. It, therefore, seems doubtful if all the multitude of animal and plant species could appear by mutations.

Moreover the cases of amazing resemblance of the mimics with their models, harmonization of animal colours with their surroundings and relationship between position of nectaries in flowers and length of proboscis in their insect pollinators cannot be imagined to have developed all of a sudden by mutations.

The discussion of the theories of evolution given above indicates that no single theory fully explains the mechanism of evolution. The modern view about the mode of evolution is that probably evolution occurs by natural selection which operates on discontinuous evolution or mutations instead of small variations as held by Darwin. This is a reconciliation between Darwin's and De Vries' theories and is called Neo-Darwinism or Neo-Darwinian theory of evolution.

TEST QUESTIONS

1. Enunciate the theories of Organic Evolution and explain the one which in your opinion is the most convincing.
2. Give an account of Darwin's theory of Natural Selection. What are the objections to it ?
3. What is Lamarckism ?
4. State and explain the Mutation Theory of Evolution.
5. Discuss Weismann's theory of the continuity of germplasm. What light it throws on Lamarckism ?
6. What are Neo-Darwinism and Neo-Lamarckism ?

GLOSSARY

The terms given below are taken from this text.

A

Abdomen. Part of the body behind the thorax and with principal digestive organs. Hindermost part of the insect body.

Abducent nerve. The sixth cranial in vertebrates.

Absorption. Passage of dissolved material through the mucous membrane of gut into blood and lymph vessels,

Accommodation power. Ability to change the focus of the eye to see objects at varied distances.

Acetabulum. A cup-like depression on either side of the pelvic girdle for articulation of the head of the femur in tetrapod vertebrates.

Acinus. A multicellular gland or a small sac in a lung.

Acquired character. A character developed by an individual during its own life.

Adaptation. Ability of living objects to adjust themselves.

Adipose tissue. Fatty tissue.

Adrenal gland. A ductless gland on or near each kidney.

Adrenalin. A hormone secreted by the medulla of the adrenal glands.

Afferent. Incoming duct or nerve to an organ.

Air-bladder. A gas-filled organ associated with the alimentary canal in bony fishes.

Alimentary canal. A digestive tract or a tube pertaining to food.

Allantois. An embryonic structure found in reptiles, birds and mammals.

Allelomorph (or Allele). One member of the pair of contrasting characters.

Alternation of generations. An alternation of sexual and asexual generations in the life-cycle of an organism.

Alveolus. A small sac or pit such as air-sac in the lung of a higher vertebrate.

Amitosis. Direct division of a cell without chromosomal activity.

Amnion. An inner embryonic membrane in a terrestrial vertebrate.

Amoeboid movement. Locomotion by pseudopodia as in *Amoeba.*

Amphiaster. A complete mitotic figure in a dividing cell.

Amphibious. Capable of living both on land and in water.

Amphimixis. Mixing of nuclear material from two different cells or orgnisms.

Ampulla. A sac or bulb-like dilatation.

Amylase. An enzyme secreted by pancreas, converts starch into sugar.

Anabolism The building up phase of metabolism.

Analogous. Similar in function but different in structure and origin.

Anaphase. Stage of mitosis when the chromatids separate and move to the opposite poles of the spindle.

Anatomy. The science that deals with the structure of organic bodies.

Antenna. A sensory appendage on the head of certain Arthropods.

Anterior. A front or head end of the body.

Anus. The posterior opening of the alimentary canal.

Appendicular skeleton. Portion of the skeleton comprising girdles and limb bones.

Aorta. The largest artery, carries blood away from heart.

Aortic arch. The largest artery arising from the heart in vertebrates.

Appendage. A movable projection from the body of an animal.

Aquatic. Pertaining to or living in water.

Aqueous humour. A watery fluid present in aqueous chamber of the eye.

Arboreal. Pertaining to or living on trees.

Areolar tissue. A type of connective tissue in vertebrates with white and yellow fibres.

Arteriole. A small branch of an artery.

Artery. A blood-vessel carrying blood away from the heart.

Asexual reproduction. Reproduction without sex cells.

Assimilation. Conversion of digested food into protoplasm.

Aster. The rays and the centriole in a mitotic figure.

Asymmetry. A condition in which two sides of an animal are dissimilar.

Atlas. The first vertebra modified for articulation with the skull.

Atrium. Receiving chamber of the heart.

Auditory. Pertaining to the organ of hearing.

Auricle. Chamber of the heart that receives blood from the veins.

Autonomic nervous system. A part of the nervous system that controls the involuntary muscles.

Axial skeleton. The part of the vertebrate skeleton lying in the main axis of the body.

Axon. A nerve-cell process that carries impulses away from the cell.

B

Backbone. The vertebral column.

Bacteria. Unicellular, microscopic plants lacking chlorophyll and definite nucleus.

Baleen. The whale bone, transverse plates of bone hanging from the upper jaw in the mouth of toothless whales.

Barb. Lateral process given off from the main-axis (rachis) of a feather in birds Small spine-like process present at the base of thread-like filament of a nematocyst.

Barbule. A process of a barb in a feather.

Biconcave. Bulging inwards on both sides.

Bicuspid valve. A valve of two flaps guarding the left auriculo-ventricular aperture in the mammalian heart. It is called Mitral valve.

Bilateral symmetry. A condition in which right and left halves of the body are mirror images of each other.

Bile. Secretion of liver in vertebrates.

Binary fission. An asexual type of reproduction in which an organism divides into two apparently equal halves.

Binary nomenclature. A system of naming animals in which each species receives two names, the first being generic, the second the specific.

Biogenetic Law. Repetition of ancestral stages in the development of an individual.

Biology. The science of life.

Biradial Symmetry. The condition in which an animal has radially arranged parts that lie half on one side and half on the other side of a median longitudinal plane.

Bisexual. Pertaining to both male and female reproductive organs.

Bladder. A thin-walled sac containing fluid or gas, *e.g.* urinary bladder ; air-bladder.

Blastostyle. A pillar-like individual of a hydroid colony that forms the medusa buds.

Blastula. A hollow sphere of cells, resulting from the cleavage of the egg.

Blind spot. The point where the optic nerve pierces the retina of a vertebrate eye.

Blood. The fluid that circulates in vascular system of many animals.

Blood corpuscles. The cells present in the plasma of the blood.

Blubber. A thick layer of fat beneath the skin to prevent the loss of heat in aquatic animals like whales, seals.

Bowman's capsules. (After Sir William Bowman, English Physician) A cup-shaped end of a urinary tubule of a kindney.

Brachial. Pertaining to the upper part of the fore-limb of a vertebrate.

Branchial. Referring to gills.

Body-cavity. The space between the body wall and internal organs.

Bone. A hard skeletal tissue peculiar to vertebrate.

Botany. The science of plant life.

Brain. The anterior enlarged part of central nervous system.

Breed true. To produce all the offspring with the same characters as the parents.

Bronchus. One of the two main branches of the trachea in lung-breathing vertebrate.

Buccal cavity. Mouth cavity.

Bud. Part of an animal that grows out to form a new individual.

Budding. A reproduction in which new individuals arise by budding.

Bulla. A hollow bony growth in the middle ear.

C

Caecum. A blind side tube at the beginning of the large intestine.

Calcaneum. The heel bone.

Calcareous. Composed of lime or calcium salts.

Canine teeth Pointed teeth; one on either side of the jaw.

Capillary. A minute vessel with one cell thick wall, connecting artery and vein.

Caput epididymis. The head or front end of the epididymis.

Carapace. Exokeleton of the cephalothorax in crustaceans of the dorsal part of the shell in Chelonia.

Carbohydrate. A class of food which includes the sugars and starches.

Cardiac. Referring to the heart.

Carina. Keel.

Carnivorous. Feeding upon live animal material or flesh.

Carotid artery. The principal artery carrying blood to the head.

Carpals. The wrist bones.

Carpus. Part of the fore-limb containing carpals, *i.e.* wrist.

Cartilage. A kind of connective tissue.

Cartilage. bone. A bone developed in the pre-existing cartilage (It is also called replacing bone).

Catabolism or Katabolism. The destructive or breaking down phase of metabolism.

Caterpillar. The larva of butterflies and moths.

Caudal. Referring to the tail.

Cell. A mass of protoplasm containing a nucleus or unit of structure and function in orgnisms.

Cellular. Pertaining to or consisting of cells.

Cell theory. The theory that all living objects are composed of cells.

Central canal. Cavity of the spinal cord.

Central nervous system. The portion of the nervous system including brain and the spinal cord.

Centriole. A small granule within the central part of the aster in the mitotic figure or a minute granule of the centrosome.

Centrum. The spool-like body of a vertebra which bears various processes

Cephalic. Pertaining to or towards the head.

Cephalothorax. Part formed by fusion of the head and thorax.

Cercaria. One of the larval stages of flukes.

Cerci. Paired jointed appendages at the end of abdomen in some insects.

Chelicerae. The anterior appendages of arachnids.

Cerebellum. A part of hind brain.

Cerabral. Pertaining to the vertebrate brain.

Cerebral hemisphere. Part of the fore-brain behind the olfactory lobes.

Chiasma. The crossing.

Chaeta. A bristle-like structure in the body-wall of many annelids, used as organ of locomotion.

Chitin. The nonprotein material secreted in the exoskeleton of arthropods and some other animals.

Chlorophyll. Green pigment in most plants and few animals, active in photosynthesis.

Choloroplast. The chlorophyll-bearing body.

Chordae tendineae. Thread-like cords connecting the values to the ventricular walls of the heart in mammals.

Chordate. Pertaining to or member of the phylum Chordata

Chorion. An outer embryonic membrane in mammals.

Choroid. The middle vascular coat of vertebrate eye-ball between sclerotic and retina.

Chromatin A dark staining material of the nucleus of the cell.

Chromosome. A dark staining body formed during cell division.

Cheysalis. Pupa of a butterfly.

Chyme. Semifluid condition of the food leaving the stomach.

Cilia. Hair-like cytoplasmic processes, used by certain protozoans for locomotion.

Circulation. Movement of blood or lymph in a body.

Class A main subdivision of the phylum.

Clavicle. The human collar-bone.

Cleavage. The division of the zygote into cells.

Clitellum. A thickened glandular portion of the skin of an earthworm, used in the formation of the cotheca.

Chromatid. One of the two parts of a chromosome during mitosis.

Chromomere. One of the bead-like granules on a chromosome.

Cloaca. Common cavity at the posterior end of the body into which the intestinal, urinary and genital canals open.

Clypeus. A chitinous plate covering the head of insects.

Cnemial crest. The ridge on the front face of tibia.

Cnidoblast. A type of cell in coelenterates which develops sting or nematocyst

Cnidocil. A small hair-like process projecting from the cnidoblast.

Cocoon. A covering that protects a mass of eggs, larva, pupa or even the adult stage of certain animals.

Coelenteron. A single cavity of coelenterates ; also called gastro-vascular cavity.

Coeliac. Pertaining to abdomen.

Coelom. Space between the body wall and the viscera.

Coenosarc. The inner cellular part of the hydroid colony.

Cochlea A division of the inner ear, coiled in higher vertebrates.

Colleterial gland. The gland that provides material for the preparation of cocoon in cockroach.

Colloid. A state of matter in which particles larger than single molecules are distributed in liquid medium.

Colon. A part of large intestine.

Colony A group of individuals.

Cold-blooded Having blood at environmental temperature.

Commensalism. An association of different species of animals in which at least one benefits without harming the other.

Commissure. A strand of nerve fibres joining two similar centres or ganglia.

Compound eye. Eye composed of numerous facets.

Conjugation A temporary union of two acellular organisms for mutual exchange of nuclear material.

Conjunctiva. The thin layer of mucous membrane that covers the eye ball in front and lines the eyelids.

Connective tissue. A tissue that binds the tissues together.

Copulation The sexual union of male and female individuals.

Coracoid. A bone of the pectoral girdle.

Coral. Calcareous skeleton of certain coelenterates.

Cornea. The transparent external layer of the eye-ball.

Coronary. Pertaining to the blood-vessels of heart muscles.

Corpus albicans. A small swelling behind the pituitary body in mammalian brain.

Corpora bigemina. Two parts of an optic lobe in mammalian brain.

Corpus callosum. A band of nerve fibres uniting the cerebral hemispheres.

Corpus cavernosum. A hard structure in a penis in mammals.

Corpuscle. A minute structure as blood corpuscle.

Cortex. The outer part of an organ.

Cowper's glands. (After English anatomist Cowper). A pair of glands opening within the urethra of male in mammals.

Cranial. Pertaining to skull or brain.

Cranium. The skull or the brain case.

Cretinism. A disease caused by the abnormality of the thyroid gland.

Cribriform plate. The perforated front wall of the brain case.

Crop. Enlargement of digestive tract for temporary storage of food.

Cross fertilization. Fusion of gametes from different individuals.

Cross-breeding. Mating of two individuals having no family relationship.

Crossing over. The process in which homologous chromosomes break and exchange corresponding segments.

Crura cerebri. Two longitudinal bands of nervous matter in the brain.

Cutaneous. Pertaining to skin.

Cuticle. A thin non-cellular external covering of an organism.

Cyst. An organism enclosed in a thickened resistant wall.

Cysticercus. The bladder worm or enclosed stage in the life-history of tapeworm.

Cytology. The science that deals with the structure and functions of cells.

Cytoplasm. The protoplasm of the cell without the nucleus.

Cyclosis. The rotary movement of the protoplasm in certan cells.

D

Dactyle. Pertains to finger or toe.

Dendrite. A process of a nerve-cell that conducts impulses towards a cell body.

Dental formula. The formula which expresses the number of each kind of teeth in a particular mammal.

Dentary. The only bone of the lower jaw in mammals, one of the several bones of the lower jaw.

Dentine. The material which composes the principal mass of a tooth.

Dermis. The deeper layer of the skin.

Deutoplasmic. Pertaining to non-living substances in a cell.

Diabetes. A disease due to deficiency of insulin.

Diaphragm. The muscular transverse partition which separates the thorax from the abdomen in higher vertebrates.

Diencephalon. The part of brain behind the cerebrum.

Digestion. Process of preparing food for absorption.

Digit. A finger or toe.

Digitigrade. Walking on the toes.

Dihybrid. The progeny of parents that differ in two characters.

Dimorphism. Difference of forms such as in size, structure, colour and form etc. between two types of individuals of the same species.

Dioecious. Separate male and female individuals of the same species.

Diploblastic. With two germ layers.

Diploid. Having the chromosomes in pairs.

Distal. Away from the point of attachment.

Diurnal. During daytime.

Diverticulum. A sac-like outgrowth from a tubular organ.

Dominant. In genetics, a member of a pair of genes which manifests itself even when its contrasting gene is present.

Dorsal. The upper side.

Ductless gland. A gland that pours its secretion directly into the blood.

Duodenum. Anterior part of small intestine.

Dura mater. The outermost membrane that covers the brain or the spinal cord.

Dysentery. A disease caused by *Entamoeba histolytica*.

E

Ecology. The study of an organism in relation to its environment.

Ectoderm. The outer layer of cells in an embryo.

Ectoparasite. A parasite living on the outside of the body of host.

Ectoplasm. The outside layer of protoplasm in a cell.

Efferent. Leading or conducting away from an organ.

Egg. The female gamete or ovum produced by a female organism.

Ejaculatory Duct The semen carrying duct.

Elytron. Modified front wing of beetles.

Embryo. An organism in an early stage of its development.

Embryology. The study of development of an organism.

Enamel. The hardest whitish substance that covers the crown of a vertebrate tooth.

Encyst. To get enclosed in a sac or cyst.

Endocrine gland. A ductless gland that pours its secretion or hormone directly into the blood.

Endocrinology. The study of ductless glands.

Endoderm. The inner cell layer of the wall of the gastrula and its later derivatives.

Endolymph. A watery fluid filling the internal ear.

Endoparasite. A parasite living within the body of its host.

Endopodite. An inner part of a biramous appendage in certain arthropods.

Endoskeleton. An internal supporting framework of an animal.

Enteron. The intestinal or digestive cavity.

Entomology. The study of insects.

Environment. The surroundings of an organism.

Enzyme. A substance produced by living cells that causes specific chemical changes.

Epidermis. The outer cellular layer of skin.

Epididymis. A long coiled tube attached to the testis in mammals.

Epiphysis. The pineal body or end of a limb bone.

Epiglottis. A flap guarding the opening of the wind pipe.

Epithelium. A layer of cells covering a surface or lining a cavity.

Erepsin. An enzyme mixture secreted by the intestinal glands.

Erythrocyte. A red cell of the blood.

Estrogen. Female hormone secreted in the ovary.

Eugenics. The study of improving human race by the application of knowledge of heredity.

Eustachian tube. The passage between the middle ear and pharynx.

Evolution. The gradual change of simple forms of life into complex forms.

Excretion. The elimination of nitrogenous waste material.

Exopodite. The outer part of the biramous appendage of certain arthropods.

Exoskeleton. The external supporting structures of an animal.

Expiration. The elimination of air from the lungs in a vertebrate.

Extracellular. Outside the cell.

F

F_1, F_2. Abbreviations for the first and second filial generations.

Facet. A small articular surface on a bone.

Faeces. The waste material eliminated from the alimentary canal.

Fallopian tube. The mammalian oviduct.

Fang. Hollow or grooved tooth of a poisonous snake for injecting poison.

Fauna. The animal life of a region.

Femoral. Pertaining to leg.

Fenestra. A spot on the head of an insect near the antenna.

Fenestra ovalis. An oval opening in the bone between the middle and inner ear.

Fenestra rotunda. A round opening in the bone between the middle and inner ear.

Ferment. See enzyme.

Fertilization. The fusion of gametes of opposite sexes or union of egg and sperm.

Fibre. A greatly elongated thread-like cell.

Fibril. A small fibre.

Fibrin. An insoluble protein precipitated as threads in a clotted blood.

Fibrinogen. A protein substance in the blood that is changed to fibrin during clotting.

Fin rays. Supporting rods of the fins.

Fission. Divison into two or more parts.

Fissure. A groove.

Flagellum. A long whip-like cytoplasmic process of a cell or single-celled animal.

Flame cell. A hollow excretory cell.

Flocculus. One of the lateral lobes of the cerebellum in the brain of rabbit, pigeon.

Flora. The plant-life of a region.

Foetus. A post-embryonic or advanced stage of a mammalian embryo.

Foetal membranes. Amnion, chorion and allantois.

Follicle. A covering of cells round egg or hair base.

Foramen. An opening in a bone for blood vessel or nerve.

Fossa. A small depression in a bone.

Fossil. The remains or impressions of past life preserved in rocks.

Free living. Not parasite or attached.

G

Gall bladder. A small sac associated with the liver to store bile.

Gamete. A mature sex cell, sperm or egg.

Gametogenesis. The process of gamete formation.

Ganglion. A mass of nerve cells on a nerve.

Gastric. Pertaining to the stomach.

Gastro-vascular. A cavity in coelenterates functioning both for digestion and circulation.

Gastrula. A two-layered embryonic stage.

Gene. An ultra-microscopic unit of inheritance located on a chromosome.

Genetics. The study of inheritance of characters from one generation to another.

Genital. Pertaining to the reproductive system or organs.

Genus A group of several related species or subdivision of a family.

Geology. The study of earth.

Germ cell. Gametes or cells which produce gametes.

Germ plasm The protoplasm of the germ cells

Germinal epithelium. The epithelium of ovary or testis.

Germ layer. One of the primary cell layers in an embryo.

Germinal variation. The variation due to some change in the germ cell.

Gestation The period between fertilization and birth of offspring in mammals.

Gill. An organ for aquatic respiration.

Gill arch. The wall bearing gills.

Gill slit An aperture in the pharyngeal and body walls of chordates.

Gizzard. A muscular organ in the alimentary canal of animals like earthworms, insects and birds.

Gland. An organ of secretion or excretion.

Glenoid cavity A socket on the pectoral girdle for articulation of bone of upper arm.

Glomerulus. A mass of coiled capillaries in Bowman's capsule of the vertebrate kidney.

Glossa. A portion of the mouth parts of certain insects.

Glottis. The opening from the pharynx into the trachea.

Glycogen. A kind of carbohydrate food stored in liver and muscles. It is also called animal starch.

Goblet cell An epithelial cell that secretes mucus.

Goitre. Morbid enlargement of thyroid gland leading to swollen neck.

Golgi bodies. A group or network of rod-like structures in the cytoplasm near the nucleus.

Gonad. Reproductive organ like testis or ovary.

Gonangium. The reprod uctive individual of a hydroid colony,

Gonotheca. The covering of gonangium or blastostyle.

Graafian follicle. A cellular covering of the mammalian ovum in the ovary.

Gregarious. An animal that lives in a group of similar animals.

Grey matter. A part of the brain and spinal cord containing nerve-cells and nerve-fibres both.

Gullet. Another name for oesophagus.

Gut. Alimentary canal.

H

Habitat. The natural dwelling place of an organism.

Haemocoel. The body-cavity containing blood or blood space.

Haemoglobin. A protein pigment of blood capable of absorbing oxygen and is red when combined with it

Hair follicle. A deep pit of epidermis round the root of hair.

Hallux. The first or inner digit of the hind-foot in tetrapoda.

Haploid. The reduced or halved number of chromosomes.

Haversian canals. Tubular cavities in the bone containing blood-vessels and nerves.

Haversian system. All the lamellae (lacunae and canaliculi) round a Haversian canal form the Haversian system.

Hepatic. Pertaining to liver.

Herbivorous. Feeding chiefly on herbs and grasses.

Heredity. The study of transmission of characters from parents to offspring.

Hermaphrodite. An individual possessing both male and female reproductive organs.

Heterodont Having many kinds of teeth.

Heterozygous. A condition in which an individual has unlike genes for a character.

Hibernation The winter sleep. Passing of winter in a dormant or inactive state.

Hippocampal lobe. The ventral lobe of cerebral hemisphere in mammalian brain.

Histology. The study of tissues.

Holometabolous. Having complete matamorphosis.

Homologous chromosomes. Chromosomes bearing the genes of the same characters.

Homologous organs. Organs structurally similar, functionally different.

Homoyzygous. A condition in which an individual has two alike genes of a character.

Hormone. A chemical regulator secreted by a ductless gland directly into the blood.

Humour. Fluid of a vertebrate eye.

Hyaline. Clear.

Hybrid. See heterozygous.

Hydranth. The flower-like feeding polyp of a hydroid colony.

Hydroid. Pertaining to Hydrozoa.

Hydrorhiza. The horizontal fixing part of the hydroid colony.

Hydrotheca. The protective covering of the polyp.

Hypostome. The structure below and surrounding the mouth in coelenterates.

I

Ileum. The last portion of the intestine.

Iliac artery. An artery of the hind limb.

Ilio-lumbar artery. The artery carrying blood to the back muscles in the pelvic region.

Ilio-lumbar vein. The vein returning blood from the muscles in the pelvic region.

Imago. The adult insect.

Impulse. The message carried by a nerve.

Inbreeding. The mating or crossing of closely related individuals.

Incisor. A front tooth of mammals, designated for cutting.

Incomplete dominance. The equal appearance or blending of two unlike characters in the offspring resulting from a cross of these characteristics.

Incubation period. The interval between infection and appearance of symptom of disease.

Incus. The anvil-shaped ear ossicle.

Independent assortment. Segregation of characters independently of other characters.

Infundibulum. A down pushing of the diencephalon of the brain.

Ingestion. The taking of the food by an organism.

Inguinal canal. The passage between the abdomen and scrotal sac.

Insectivorous. Insect-eating animal.

Instar. Larval stage between two moults as in the development of insects.

Insulin. Hormone secreted by islands of Langerhans of the pancreas

Integument. The skin.

Intercellular. Between the cells.

Intercostal. Between the ribs.

Intermediate host. The host in which the parasite spends the asexual part of the life history.

Interstitial celle. The cells of testes which secrete sex hormones.

Intervertebral disc. A thin pade of fibro-cartilage between the two vertebrae.

Intestine. Portion of alimentary canal extending beyond the stomach.

Intracellular. Inside or within the cell or cells.

Intra-specific. Among the individuals of the same species.

Invertebrate. An animal without the vertebral column.

Iris. The coloured part of the eye perforated by pupil.

Irritability. The ability of living things to respond to stimuli.

Islands of Langerhans. Parts of pancreas which act as ductless gland to secrete insulin.

J

Jugular Pertaining to neck.

K

Karyokinesis. Mitosis.

Karoysome. A part of the chromatin which forms a distinct body in the nucleus.

Katabolism. (See catabolism).

Keel. A thin plate like projection from the ventral surface of the sternum in a bird.

Kidney. A glandular organ which excretes urine.

L

Labial· Pertaining to lips.

Labium. The lower lip of an insect.

Labrum. The upper lip of an insect.

Labyrinth. The internal ear.

Lacrymal gland. The tear gland.

Lacuna. A small space in cartilage or bone containing cell during life.

Lamella. Layer or plate.

Larval An active immature stage in the post-embryonic life of many animals.

Larynx. The voice box.

Lateral. The sides of the body.

Lens. A transparent structure just behind the pupil in a vertebrate eye.

Leucocyte. A white blood corpuscle.

Liber Kiihn's glands. The intestinal glands.

Lienogastric artery. The artery supplying blood to the spleen and stomach.

Life-cycle. All the stages from the egg to the adult of an organism.

Ligament. A strand of white fibrous connective tissue that joins two bones.

Lingual. Pertaining to the tongue.

Lipase. An enzyme which breaks fats.

Liver. A large gland associated with the digestive tract.

Lumbar. The part of the body just behind the thorax.

Lumen. A cavity of a tubular organ.

Lung. The air-breathing organ of tetrapods.

Lymph. A colourless liquid which circulates in the lymph vessels.

Lymphatic system. A system of spaces and vessels carrying lymph into larger veins.

M

Macrogamete. The larger or female gamete.

Macronucleus. The larger nucleus found in some protozoans.

Maggot The Legless larva of a fly.

Malleus. The hammer-like ear ossicle in mammalian ear.

Malpighian body. Structure in the vertebrate kidney composed of Bowman's capsule and the glomerulus.

Malpighian layer. The innermost actively dividing layer of epidermis

Mammary gland. The gland of female mammals that produce milk.

Mandible. A jaw, the lower jaw in vertebrates; either jaw in an arthropod.

Mantle. A fold of body-wall which envelops the soft parts of a mollusk and seeretes the shell.

Manubrium. A cylindrical structure in the centre of the subumbrellar surface of a medusa, bears mouth.

Manus. The hand

Marine. Pertaining to sea.

Mastication. The chewing of food.

Matrix. The intercellular material or ground substance of a tissue.

Maxilla. A mouth-part in certain Arthropods.

Meatus. The external auditory canal.

Mediastinum. A central space in the thorax of mammals between the lungs containing heart, great vessels. oesophagus and trachea.

Medulla oblongata. The hindermost part of the vertebrate brain.

Medullary sheath. A layer of fat between the neuraxis and neurilemma of medullated nerve-fibre.

Medullated nerve-fibre. The nerve-fibre with medullary sheath.

Medusa. The sexual stage of some coelenterates.

Meganucleus. The larger nucleus.

Meiosis. A cell division in which number of chromosomes is halved

Melanin. The black pigment.

Membrane bone A bone which is formed in connective tissue.

Membranous labyrinth. The internal ear.

Merozoite. An individual formed by the division of schizont.

Mesenteric. Pertaining to the mesentery

Mesoderm. The middle layer of embryonic cells between the ectoderm and endoderm.

Mesogloea. The middle non-cellular jelly like layer in coelenterates like Hydra.

Mesothorax. The middle segment of the thorax in insects.

Metabolism. The sum-total of the process of building up and tearing down of protoplasm.

Metacarpal. Proximal bone of the hand.

Metacarpus. The palm.

Metagenesis. Alternation of generations.

Metamere. One of the similar segments.

Metamorphosis. A sudden change in structure occurring in the life-history of an organism from the larva to an adult.

Metaphase. The stage in mitosis in which the chromosomes are arranged on the equatorial line.

Metatarsals. Proximal bones of the foot.

Metazoa. All animals beyond protozoa or the multicellular animals.

Microgamete. The small or male gamete.

Micronucleus. The smaller nucleus.

Microorganism. The organisms that can be seen with the aid of a microscope.

Milk teeth The first or temporary set of teeth in young mammals.

Mimicry. Resemblance of one animal to another for protection.

Miracidium. The first larval stage of flukes.

Mitochondria. Minute granules, rods or threads in the cytoplasm.

Mitosis. Cell divisions during which the chromosomes are duplicated and separate upon a spindle.

Mitral valve. The bicuspid valve.

Molar. A kind of tooth adapted for grinding food.

Monoecious. Bisexual or having both male and female gonads in the same individual.

Monohybrid. The offspring of parents differing in one character.

Morphology. The study of form and structure of an organism.

Morula. A ball-like stage of early embryology.

Motor nerve. The nerve carrying impulse from central nervous system to the muscle.

Mucous. Producing or pertaining to mucus.

Mucus. A slippery viscous secretion produced by mucous glands.

Multicellular. Pertaining to many cells.

Muitinucleate. Having many nuclei.

Muscle. An organ producing movement or tissue containing highly contractile and greatly elogated cells.

Muscularis mucosa. A thin layer of smooth muscles in the sub-mucosa of stomach intestine and oesophagus.

Musculo-epithelial cells. The cells performing muscular as well as epithelial functions.

Mutant. An individual with mutation.

Mutation. An inherited change in an organism or sudden change in a gene resulting in a phenotypic modification.

N

Naiad. An aquatic gill-breathing nymph or larva.

Nares. The openings of nasal cavities.

Natural selection. Darwin's theory of evolution or the elimination of unfit in the struggle to live.

Nematocyst. A stinging capsule in coelenterates, produced in a cell, the endoblast.

Nephridiopore. The outer opening of an excretory tubule or nephridium.

Nephridium. A tubular excretory organ found in annelids.

Nephrostome. The inner ciliated funnel-shaped opening of the excretory tubule (Nephridium) to receive the waste material.

Nerve. A bundle of nerve-fibres to carry impulses.

Nerve-cord A compact cord made up of neurons and usually with ganglia, comprising the part of central nervous system.

Neural. Refers to nervous system.

Neuron A nerve cell with a cell body and its processes.

Nictitating membrane. The third eye-lid.

Nocturnal Active at night.

Node of Ranvier. The place on a nerve-fibre where the medullary sheath is restricted.

Nomenclature. Naming of the organisms.

Notochord A rod-shaped cellular body lying medially between the alimentary canal and the central nervous system in chordates.

Nucleolus. A large and deeply staining body inside he nucleus.

Nucleoplasm. The dense gelatinous material of the nucleus.

Nucleus A central mass in the protoplasm of a cell containing chromatin and controlling the various activities of the cell.

Nymph. An immature post-embryonic stage in insects with gradual metamorphosis.

O

Obturator foramen. The wide hole in the mammalian pelvic girdle.

Occipital condyle A knob at the base of the skull of a vertebrate.

Odontoid. A peg-like process on the centrum of the axis vertebra.

Oesophagus. The gullet or food pipe.

Omnivorous. Feeding on foods of both plant and animal origin.

Ontogeny. The developmental history of an individual.

Operculum. The cover of the gills in fishes and of the shell in snails

Ophthalmic. Pertaining to eye.

Optic. Pertaining to the eye or sight.

Optic lobes. Rounded or oval bodies on the dorsal side of the midbrain.

Oral. Referring to the mouth.

Orbit. The socket of the eye.

Order. A subdivision of the class in taxonomy.

Organ. A group of tissues for some specific function.

Organ of corti. The special organ of hearing in mammalian ear.

Organism. An independent living thing.

Organelle. A part of the protozoan body performing a definite function.

Osseous system. The skeletal system.

Ossicle. Small bones in the middle ear.

Ossification. The process of bone formation.

Otocyst. A primitive organ of hearing.

Otolith. A calcareous particle in the internal ear of vertebrates.

Ovary. The female gonad.

Oviduct. The duct that carries eggs from the ovary to the exterior or to the uterus.

Oviparous. Animals which lay eggs.

Ovum. The female gamete.

P

Palaeontology. The study of past life from fossils.

Palate. The roof of the mouth.

Palp. A jointed feeler on some of the mouth parts of insects.

Pancreas. A digestive cum endocrine gland.

Papilla. Any small pimple-like projection.

Paraglossa. A part of the labium outside the glossa.

Parapodium. A stump-like non-jointed appendage in polychaetes.

Parasite. An organism that lives in or on and at the expense of another organism.

Parathyroid. One of the small ductless glands near the thyroid.

Parenchyma. Soft cellular substance filling space between organs

Parietal. Referring to the walls of the coelom.

Parthenogenesis. The development of an egg without fertilization.

Patella. The knee-cap.

Pathogen. Disease-producing organism.

Pathology. Study of diseased tissues.

Pavement epithelium. Squamous epithelium.

Pectoral girdle. The shoulder girdle connecting forelimbs with vertebral column.

Pedipalp. The second pair of appendages in arachnids.

Pellicle. The thin outer membrane of the acellular body as in *Paramecium*.

Pelvis. Anterior enlarged end of a ureter in mammals, cavity of pelvic girdle.

Penis. The copulatory organ of a male animal.

Pentadactyle. Having five toes or fingers.

Peristomium. First segment in earthworm.

Pepsin. A protein-splitting enzyme in gastric juice.

Pericardium. The covering of the heart.

Perilymph. The liquid surrounding the internal ear.

Perineal. Pertains to the glands and pouches on the sides of the anus in rabbit.

Periosteum. The outer covering of the bone.

Peripheral. Towards the surface or away from the centre.

Perisarc. Non-cellular covering of the hydroid.

Peristalsis. Forcing the food along the intestine by rhythmical contractions of intestinal walls.

Peritoneum. A thin mesodermal membrane lining the abdominal cavity and covering the viscera in chordates.

Pes. Foot.

Phalanges. Bones of the digit.

Pharynx. The space between the mouth cavity and gullet.

Phrenic. Pertaining to diaphragm.

Phylogeny. The study of the origin and relationships of different groups and races of animals.

Phylum. One of the main divisions of the animal kingdom.

Physiology. The study of functions of oragns.

Pia-mater. A thin vascular covering of the brain and spinal cord.

Pigment. The colouring substance.

Pineal body. A dorsal projection from the diencephalon.

Pinna. The outer ear.

Pituitary body. An endocrine gland on the floor of the brain.

Placenta. The vascular membrane which connects the embryo with the uterus.

Plantigrade. Walking on the soles of feet.

Planula, A free living ciliated larval form of coelenterates.

Plasma The liquid part of blood or lymph.

Pleura. Membranes surrounding the lungs.

Pleural. Pertaining to the cavity which contains lungs. The membrane covering the lungs and lining the pleural cavity.

Plexus. A network of nerves or blood-vessels.

Pneumogastric. Another name for vagus nerve.

Poikilothermal. A cold-blooded animal having variable temperature

Pollex The inner digit of the fore-limb.

Polymorphism. Having many types of individuals.

Polyp. A feeding zooid with tentacles and mouth.

Pons varolii. A transverse bridge of nervous matter below the medulla oblongata connecting the right and left lobes of cerebellum.

Post-axial. The outer side of the limb.

Portal system A system of blood-vessels that begin and end in capillaries.

Portal-vein. The vein that forms capillaries before reaching the heart.

Post-caval vein. Vein that brings blood from hinder part of the body.

Posterior. Away from front end or the head.

Postzygapophysis. A process on hinder side of vertebra.

Pre-axial. The inner side of the limb.

Pre-caval. Vein bringing impure blood from the anterior part of body.

Predaceous. Animal that preys on others for food.

Proglottis. A segment of a tapeworm.

Prophase. The first stage in mitosis.

Prostate gland. One of the male reproductive glands producing part of the semen.

Prostomium. A projection in front of the mouth.

Protein. One of the basic food substances found in protoplasm.

Protoplasm. The living substance.

Proximal. Nearest to the main axis or point of attachment to the main body.

Pseudocoel. A body-cavity nor lined by peritoneum.

Pseudopodium. Temporary protoplasmic projections formed by amoebae for locomotion.

Pulmonary. Pertaining to lung.

Pupa. The inactive stage between the larva and the adult in insects with complete metamorphosis.

Ptyalin. An enzyme of saliva.

Q

Quadruped. Four-legged vertebrates.

Quartan fever. A form of malaria that recurs every 72 hours. (4th day).

Queen. The fertile female in the colony of social insects as bees.

R

Rachis. The central axis of a feather or of the sea-pen.

Radial symmetry. Having similar parts arranged like the spokes of a cycle wheel.

Ramus. Half of a jaw.

Ramus communicans. A nerve connecting the sympathetic ganglion with spinal nerve.

Recapitulation. Repetition in the development of an individual organism of its ancestral history.

Recessive character. A character that manifests only when both its genes are similar.

Rectum. The last part of the intestine.

Rectus muscle. One of the four straight muscles of the eye.

Redia. One of the larval stages of flukes.

Reduction division The maturation division of a germ cell in which the chromosomes are reduced to haploid number.

Refection. The habit of eating one's own faeces as in rabbit.

Reflex action. An automatic response to a stimulus without the will of an animal.

Regeneration. Regrowth of the lost part.

Renal. Pertaining to kidney.

Rennin. An enzyme of gastric juice that curdles milk.

Reproduction. The production by an organism more individuals of its kind.

Respiration. The exchange of gases between cells and their surroundings.

Response. Reaction to a stimulus.

Retina. The innermost sensory layer of the eye-ball.

Rhinal fissure. A grove on the ventral side of the cerebral hemisphere.

Rods and cones. The receptor cells in the retina of the eye.

Rostellum. Anterior projection of the scolex in tapeworm.

Rudimentary. Underdeveloped functionless organs.

Ruminant. A cud-chewing mammal as the cattle.

S

Sacculus rotundus. A somewhat rounded structure at the end of small intestine.

Sacrum. Bone formed by the fussion of sacral vertebrae in the pelvic region.

Sagittal section. A median longitudinal vertical section.

Saliva. Secretion of salivary gland.

Salivary gland. Digestive glands in buccal-cavity.

Sarcolemma. A thin membrane covering a striated muscle-cell.

Sarcoplasma. The cytoplasm of a muscle-cell.

Schizogony. Division of schizont into merozoites.

Schizont. A cell ready for division into many parts.

Sciatic. Pertainning to thigh.

Sclerite. Hardened body wall plate as in Arthropoda.

Sclerotic. The dense fibrous outer coat of the eye-ball.

Scolex. The knob-like head of tapeworm.

Scrotum. The sac that contains testes.

Sebaceous gland. An oil-secreting gland associated with hair follicle.

Sebum. The oil.

Secondary sexual characters. The features other than reproductive organs, by which male and female of a species differ.

Sedentary animals. The fixed animals.

Segment. One part of a segmented animal.

Segregation. Separation of homologous chromosomes and genes during gamete formation.

Self-fertilization. Fusion of male and female gametes of the same individual.

Semen. The fluid that carries the spermatozoa in most male mammals.

Semicircular canals. The equilibrium-maintaining canals of the vertebrate ear.

Seminal. Pertaining to spermatozoa.

Sensory cell. A cell sensitive to stimuli.

Septum. Partition.

Serum. A clear liquid which separates from blood when a clot is formed.

Sesamoid bone. A small bone developed by ossification in the tendon.

Setae. Minute bristles embedded in the body-wall of annelids like earthworm.

Sigmoid notch. A deep groove in the ulna for humerus.

Somatic cells. Body cells except those of gonads.

Species. A division of a genus in classification of animals, including individuals.

Sperm or spermatozoon. A male gamete.

Spermatheca. A sac that receives and stores sperms in the female system.

Sphincter. A ring of smooth muscles round an aperture to control its size.

Spinal column. The backbone or vertebral column.

Spinal nerve. The nerve arising from spinal cord.

Spindle. A structure of fibres formed in the cytoplasm during cell division.

Spiracle. An opening of tracheal system in inseots ; first gill-slit in cartilaginous fishes.

Spleen. A large organ lying near the stomach in which the red blood corpuscles are stored.

Sporozoite. A minute body formed by division of the zygote in malarial parasite.

Statocyst. A sac-like balancing organ of medusa.

Steapsin. An enzyme of pancreatic juice, acts on fats, now called lipase.

Sternum The breast-bone in vertebrate skeleton.

Stimulus. A change in enviroment that makes the organism to react.

Stomodaeum. Anterior part of the alimentary canal lined by ectoderm.

Stratum corneum. The outer horny layer of the skin.

Stratum malpighii. The innermost layer of epidermis.

Striated muscle. The striped or voluntary muscle.

Subclavian artery. Artery leading to the arm.

Subcutaneous. Beneath the skin.

Succuss entericus. The intestinal juice.

Supra Above.

Symbiosis. The living together of two different organisms.

Sympysis. The union of bones in the median line.

Synapsis. The pairing of homologous chromosomes during meiosis.

Syrinx. A sound producing organ situated at the junction of trachea and the bronchii.

System. A group of organs working together.

Systole. The contraction of the heart.

T

Tactile. Pertaining to the sense of touch.

Tarsus. The distal part of the leg in insects.

Taste bud. Receptor organ of taste.

Taxonomy. The science that deals with the classification of organisms.

Telophase. The last stage of mitosis in which the cell divides.

Temporal lobe. The lateral lobe of the cerebral hemisphere.

Tendon. A tough connective tissue binding the muscle to a bone.

Tentacle. A flexible filament-like structure as in *Hydra*

Tergum. One of the dorsal plates of exoskeleton in the arthropods.

Terrestrial. The land forms.

Testis. The male sex organ that produces sperms.

Testosterone. Male hormone secreted by the testis.

Thalamencephalon. Another name for diencephalon.

Thoracic. Pertaining to the chest.

Thorax. The chest or the part of the body behind the head or neck.

Thymus. A ductless gland below thyroid in mammals.

Thyroid. A ductless gland in the neck of a vertebrate.

Thyroxine. Secretion of the thyroid gland.

Tissue. A group of cells performing a definite function.

Toxin. A poisonous substance.

Trachea. The wind pipe carrying air from the pharynx to the lungs.

Trichocyst. Small bodies in the ectoplasm of certain ciliates.

Tricuspid. A valve of three flaps between the right auricle and right ventricle

Triploblastic When an animal develops from three germinal layers.

Trochanter. The second segment of the leg of an insect between the coxa and femur.

Trophozoite. The feeding stage in the malarial parasite.

Tryspin. An enzyme of pancreatic juice, converts proteins into proteoses and peptones.

Turbinals. The coiled scroll-like bones in the olfactory capsules in mammals.

Tympanum. The cardrum.

Tympanic cavity. The cavity of the middle ear.

Typhlosole. A mid-dorsal fold in the intestine of earthworm.

U

Unguligrade. Animal that walks on the tips of the digits.

Unicellular. One-celled organism.

Unisexual. Pertaining to one sex only, *i.e.*, male or female.

Unstriated muscles. The muscle cells without transverse lines.

Urea. The nitrogenous waste material.

Ureter. The duct which carries urine from the kidney to the urinary bladder or cloaca.

Urethra. The duct that carries urine from bladder to external opening in the body.

Urinary bladder. A sac that stores urine.

Urine. The liquid waste filtered from the blood in the kidney and excreted by the bladder.

Uriniferous tubule. A fine coild tube in the kidney.

Uterus. An enlarged posterior portion of the oviduct in which eggs are retained for development.

Utriculus. The upper chamber of the internal ear.

V

Vacuole, A small fluid-filled space in the cytoplasm of a cell.

Vagina. The posterior part of reproductive tract of the female opening to the exterior.

Variation. The difference among the individuals of the same species.

Vascular. Pertaining to blood-vessels.

Vas deferens. A large sprems carrying tube.

Vas efferens. A fine tube taking sperms from the testis to the vas deferens or kidney.

Vein. A vessel carrying blood towards the heart.

Vena cava. The large vein entering the heart.

Ventral. The lower side.

Ventricle. A small cavity in the heart or brain.

Venulele. A small branch of the vein.

Vertebra. One of the segments of the back-bone.

Vertebral columan. The back bone.

Vestigial organ. A reduced structure.

Vibrissae. Long stiff sensory hair round the mouth, whiskers.

Villus Finger like projections of the intestinal wall.

Viscera The internal organs of an animal.

Vitreous humour. A clear jelly-like mass behind the lens in a vertebrate eye.

Viviparous animals. The young are born alive.

Vocal chords. Sound producing cords in larynx.

Voluntary muscle. The muscle controlled by the will of an organism.

W

Warm-blooded. Animals (Birds and Mammals) whose body temperature remains constant irrespective of the atmospheric temperature.

White corpuscle. Irregular, colourless cells of the blood, or Leucocytes.

White fibres. Bundles of inelastic unbranched wavy fibres in the areolar tissue.

White matter. Nervous tissue containing nerve fibres only.

Y

Yellow fibres. Branched elastic fibres of areolar tissue.

Yolk The food material in the egg.

Z

Zoogeography. The branch of zoology that deals with the geographic distribution of animals.

Zooid. Kind of an individual in a hydroid colony.

Zoology. The study of animal life.

Zygote. A fertilised egg or a cell formed by fusion of male and female gametes.

APPENDIX

PUNJAB UNIVERSITY QUESTION PAPERS

Pre-Medical—Biology Paper B (Zoology)

APRIL, 1968

1, Describe the structure of medusa of *Obelia*. How does it differ from its polyp ?

2. Describe the reproductive organs of *Pheretima posthuma* in relation to the segments of the body. What is the advantage of being hermaphrodite to this animal ?

3. Give an account of the respiratory system in cockroach. In what respects does it differ from that of earthworm ? Which of the two is more efficient and why ?

4. (*a*) Describe the functions of blood in a vertebrate.

(*b*) Tabulate the differences between an artery and a vein.

5. Give an illustrated account of brain of rabbit. Indicate the special mammalian features reflected in its structure.

6. Describe in detail the urinogenital system of female rabbit.

7. Write what you know about the theory of natural selection. How does it differ from the mutation theory ?

8. Write brief notes on any five of the following :—

Coelom, Placenta, Dental formula, Pectoral girdle of Rabbit, Coral, *Hyla*, Spider and Kangaroo.

APRIL, 1969

Attempt any *five* questions. Illustrate your answers with neat and accurately labelled diagrams.

1. Write all you know about *Meiosis* in an animal cell. What is the significance of *Meiosis* ? 8,2

2. Describe in detail the microscopic structure of *Paramecium*. Write all you know about locomotion, nutrition and osmo-regulation in this animal.

· What is Metagenesis ? Describe this phenomenon with reference to the life-history of a colonial coelenterate studied by you. What is the significance of this phenomenon to the animal ? 2,6,2

4. Describe the nervous system of *Periplaneta* and compare it with that of Earthworm. What is the fundamental difference between the nervous system of an invertebrate and that of a vertebrate ? 5,3,2

5. Give an account of the afferent blood vessels of Rabbit. What is the difference between blood and lymph ? 8,2

6. Describe the structure of the ***Mammalian*** ear and show how it performs the functions of perception of sound and maintenance of equilibrium. 6,4

7. What do you understand by Organic Evolution ? Discuss the *Embryological* or *Anatomical* evidences in favour of this doctrine. 2,8

8. Write notes on any *five* of the following :

(*a*) Central apparatus (*b*) *Islands* of *Langerhans*. (*c*) *Labium of* Cockroach (*d*) *Larynx* of Rabbit. (*e*) *Vagus* nerve of Rabbit. (*f*) *Euglena* (g) *Physalia* (*h*) *Leech*. (*i*) *Draco volans*. (*j*) *Whale*. 10

APRIL, 1970

Attempt any five questions. Illustrate your answers with neat and labelled diagrams.

1. Write an illustrated account of M**itosis** in an animal cell. How does it differ from Meiosis ? 8,2

2. Describe the process of conjugation in Paramecium. What is its significance ? 8,2

3. Describe the medusa of Obelia. How does it differ from the polyp ? 6,4

4. Draw a labelled sketch showing the reproductive organs of Pheretima. What is the advantage of hermaphroditism to the animal. 8,2

5. Describe the structure of blood in Rabbit. What are the functions of blood ? 7,3

6. What is digestion ? Describe the process of digestion in Rabbit. 2,8

7. Enumerate Mendel's law of Heredity. Discuss any *one* of these in detail. 4,6

8. Write notes on any *four* of the following :—

Planaria, Rat Flea, Echidna, Island of Langerhans, Malpighian tubules of cockroach, Cerebrum.

APRIL, 1971

Attempt any five *questions. All questions carry equal marks.*

I. Give an illustrated account of the skin of frog with a note on the function it plays during hibernation.

II. Write a detailed and illustrated account of the digestive system of *Pheretima*.

III. Describe the organs of reproduction in cockroach.

IV. Describe the structure of *Paramaecium* and write notes on the process of digestion and excretion.

V. Give a detailed and illustrated account of the male reproductive system of rabbit.

VI. Make a neat and labelled sketch of the venous system of rabbit.

VII. Enumerate theories in favour of Organic Evolution and discuss the theory of Natural Selection in detail.

VIII. Write short notes on any *four* of the following :—

Physalia, *Sepia*, Sting ray, *Draco*, Kangroo, RNA, Body louse.

PANJABI UNIVERSITY QUESTION PAPERS

Pre-Medical Biology—Paper B (Zoology)

APRIL, 1968

Note :—Attempt any *Five* questions. All questions carry equal marks.

1. Describe briefly the various methods of asexual reproduction in the Protozoan types you have studied.

2. Distinguish between any *four* of the following :—

(*a*) Amphimixis and Endomixis. (*b*) Exocrine and Endocrine glands (*c*) Bilateral symmetry and Radial symmetry. (*d*) Blood of frog and that of rabbit. (*e*) Non-Chordata and Chordata.

3. What is 'Metagenesis' ? Explain it with reference to the life-history of *Obelia*.

4. Describe the position and functions of any *four* of the following organs in *Pheretima posthuma* :—

Clitellum, Lymph Glands, Spermathecae, Brain, Gonads.

5. Describe in order the cerebral nerves of rabbit, giving their origin, distribution and nature.

6. Make labelled diagrams of any *two* of the following :—

(*a*) Alimentary canal of cockroach. (*b*) Arterial system of rabbit. (*c*) T. S. intestine of frog.

7. Enunciate the theories of Organic Evolution. Explain that which you think to be most convincing.

8. Write short notes on any *four* of the following :—

Trypanosoma, Nematocysts, *Ascaris*, *Proteus*, Tortoise, Placenta.

APRIL, 1969

Note :—*Attempt any* five *questions. All questions carry equal marks. Illustrate your answer with suitable diagrams.*

1. What is meant by 'Alternation of generations' ? Explain it with reference to the life-history of PLASMODIUM.

2. Distinguish between any *four* of the following :—

(*a*) Symbiosis and Commensalism.

(*b*) Proteolytic and Amylolytic ferments.

(*c*) Motor and Sensory nerves.

(*d*) *Culex* and *Anopheles*.

(*e*) Polyp and medusa of *Obelia*.

3. Describe the position and functions of the following :

Trichocysts, Statocysts, Setae, Colletrial glands, Semi-lunar valves.

4, Describe the Reproductive System of *Pheretima*. How is self-fertilization rendered impossible in this animal ?

5. Give a detailed account of the digestive system of Cockroach.

6. Make labelled diagrams of any *two* of the following :

(*a*) Internal structure of the heart of Rabbit *or* Sheep with arrows indicating the flow of blood.

(*b*) V.S. through the mammalian Skin.

(*c*) Male urino-genital system of rabbit.

7. What is Heredity ? Explain Mendel's laws of Heredity.

8. Write short notes on any *four* of the following :—

Taenia, Scorpion, Dog-fish, Egg-laying Mammals, Retina, Lumbar vertebra.

APRIL, 1970

1. Describe the form and structure of *Paramecium*. What are the features in which it shows morphological and physiological advance over *amoeba*.

2. What do you understand by the physiological division of labour ? Illustrate your answer with reference to *Obelia*.

Can you explain that the polyp and medusa of *Obelia* are strictly homologous structures.

3. Give a brief account of the differences between the earthworm and cockroach as regards locomotion, feeding, body-cavity and respiration.

4. Describe the nervous system of cockroach. What are the main differences between the nervous systems of invertebrates and vertebrates ?

5. What are replacing and membrane bones ? Give as many examples of these bones in the skull of rabbit.

Or,

Describe in detail the structure of the eye of rabbit.

6. Make a labelled diagram of any two of the following :—

(*a*) T. S. stomach of frog.

(*b*) Venous system of rabbit.

(*c*) Reproductive system of *Pheretima*.

7. Write a paragraph on any *two* of the following :—

Vestigial organs, Variations, Law of segregation.

8. Write short notes on any four of the following—

Leech, Crab, *Protopterus*, Kangaroo, Heversian system, Graafian Follicles.

APRIL, 1971

(*i*) *Attempt any* **Five** *questions of the following.* (*ii*) *All questions carry equal marks.* (*iii*) *Draw neat and labelled diagrams wherever necessary.*

1. (*a*) How will you obtain Amoeba and Paramecium for study in the laboratory ? 2

(*b*) Describe the process of locomotion and nutrition in Amoeba and Paramecium. 4,4

2. What is Metagenesis ? Describe this phenomenon with reference to the life-history of Obelia. What is its significance to the animal ? 2,6,2

3. Describe the external characters of earthworm. How is it well-adapted to its burrowing mode of life ? How is it a friend to the agriculturists ? 6,2,2

4. Give an account of the respiratory sytem of cockroach. In what respects does it differ from that of earthworm ? Which of the two is more efficient and why ? 6,2,2

5. Draw a neat and labelled diagram of the V.S. skin of rabbit. Give the main functions of skin. 6,4

6. Distinguish between any *four* of the following :— 10

(*i*) Replacing and membrane bones.

(*ii*) Arteries and Veins.

(*iii*) Proteolytic and Amylolytic ferments.

(*iv*) Blood and Lymph.

(*v*) Larynx and Pharynx of rabbit.

(*vi*) Ileum and Ilium.

7. What do you understand by Organic Evolution ? Discuss the Anatomical evidences in favour of this doctrine. 2,8

8. Write short notes on any *four* of the following :— 10

Tapeworm, Salamander, Kangroo, Nematocysts, Gene, Reflex action.

KURUKSHETRA UNIVERSITY QUESTION PAPERS

Pre-Medical Biology—Paper B (Zoology)

APRIL, 1967

Attempt any Five questions. Illustrate your answers with neat, accurate and labelled diagrams where necessary.

1. Describe conjugation in *Paramecium*. How does it differ from endomixis ?

2. Describe the ectodermal modifications met with in *Hydra*.

3. Give a detailed account of the reproductive system in *Pheretima*.

4. Give a detailed account of the respiratory system of cockroach.

5. Describe the skin of rabbit and compare it with that of frog. Can you give reasons for the difference ?

6. Describe the digestive system of rabbit.

7. Give a brief classification and write short ecological notes on :—(*a*) Coral ; (*b*) Liverfluke ; (*c*) Leech ; (*d*) Dogfish ; (*e*) Pigeon.

8. Explain Mendel's Law of segregation and illustrate it with an example.

9. What is organic evolution ? What proofs can you give in its favour from the comparative anatomy of animals ?

10. Write short note on :—

Trichocyst ; Velum ; Mushroom-shaped gland ; Setae ; Retina.

APRIL, 1968

1. (a) Draw a labelled diagram showing the structure of an animal cell.

(b) Distinguish between mitosis and meiosis (diagrams and detailed descriptions are not required).

2. Describe, separately, locomotion and mode of feeding in *Amoeba*.

3. What is alternation of generations ? Illustrate the phenomenon in the life-history of *Obelia*.

4. Give the external characters of an earthworm and describe its habits and habitat.

5. Describe the digestive system or the nervous system of cockroach.

6. Give a detailed account of the life-history of the silkmoth.

7. Draw a labelled diagram showing the internal structure of the heart of rabbit. Show the course of blood circulation by means of arrows in the diagram.

OR

Describe the male urinogenital system of rabbit.

8. Write short notes on any *four* of the following :—

Pancreas, Mammalian blood, Hibernation, Aves, Mutation, Gene, Natural Selection.

GURU NANAK UNIVERSITY PAPERS

Pre-Medical Biology—Paper B (Zoology)

APRIL, 1971

Attempt any five questions. Illustrate your answers with suitable diagrams.

1. How would you procure Paramecium in the laboratory? Describe in detail the structure, locomotion and asexual reproduction in this protozoon. 1,5,2,2

2. Tabulate the differences between the following :—

(*a*) T. S. of Intestine and T. S. of Stomach.

(*b*) T. S. Vein and T. S. of Artery. 6,4

3. Make labelled sketches to show the male and female reproductive organs in cockroach.

How does a male cockroach differ from a female cockroach? 4,4,2

4. Describe the following in Pheretima :—

(*a*) Structure and functions of the skin.

(*b*) A septal Nephridium.

(*c*) Copulation and cocoon formation. 4,4,2

5. Give an account of the Respiratory organs and mechanism of respiration in Rabbit. 6,4

6. Describe the course of blood from the ventricles of Rabbit's heart to different parts of the body. 6,4

7. Write a brief essay on Darwin's theory of Netural Selection. 10

8. Write short notes on any *four* of the following :—

Cerebellum, Blastostyle, DNA, Nematocyst, Spider, Scoliodon, Nereis, Flying fox.